

104

# THE 1996 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

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Y 4. SCI 2: 104/6

The 1996 National Science Foundatio...

## HEARINGS BEFORE THE SUBCOMMITTEE ON BASIC RESEARCH OF THE COMMITTEE ON SCIENCE U.S. HOUSE OF REPRESENTATIVES ONE HUNDRED FOURTH CONGRESS FIRST SESSION

FEBRUARY 22; MARCH 2, 1995

[No. 6]

Printed for the use of the Committee on Science



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# THE 1996 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

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WEDNESDAY, FEBRUARY 22, 1995

U.S. HOUSE OF REPRESENTATIVES,  
COMMITTEE ON SCIENCE,  
SUBCOMMITTEE ON BASIC RESEARCH,  
*Washington, D. C.*

The Subcommittee met, pursuant to call, at 9:33 a.m. in Room 2318 of the Rayburn House Office Building, the Honorable Zach Wamp presiding.

Mr. WAMP. Good morning, ladies and gentlemen.

Let me introduce myself if I could. I'm Zack Wamp, a freshman member from Tennessee. I represent Oak Ridge, Tennessee which is my claim to science fame, and those that serve on Subcommittees with me, both Energy and Environment and the Basic Research Subcommittee here of the Science Committee know that just about every time I grab the microphone, I remind everyone present that we're having a summit in Oak Ridge, Tennessee on June 1st and 2nd.

This summit will focus on science, energy, waste management, and technology issues. It'll be a two-day summit and it comes during the Memorial Day recess for the members of the House.

We have an outstanding delegation of representatives from the Administration and the Congressional leadership, and quite honestly the scientific community throughout the country attending Oak Ridge.

So, in opening, I want to welcome you all hear. Call the meeting to order and open with some brief comments. But first apologize to our witness and all those present because we are competing with several other activities this morning, not the least of which is the President's address at the Democratic Caucus Meeting this morning, as well as the Republicans are in conference, this meeting, as well, talking about legislation coming before the House this morning.

And I know Secretary Rice is here in this building testifying on the minimum wage.

So the members will be arriving as the morning progresses, but we will go ahead and stay on schedule and hope that the staff takes good notes and whispers in the members' ears as they come in to bring them up to speed on where we are.

I want to open this morning by reminding all of us that this past Monday we celebrated Presidents' Day, a day to honor our past Presidents.

I would like to point out that today is George Washington's Birthday, and for those of us who have toured his home at Mt. Vernon, you've seen the foundation's of George's greenhouses and barns.

George Washington was a scientist. He conducted experiments on the uses of fertilizers, growing crops, and improving his livestock.

For those of you who are unaware, George Washington introduced mules into farming. He found them to be sturdy, hardy, and most importantly, they ate less than horses.

Once again, we can learn from George as our first President. He was always looking for ways to cut the budget and reduce spending.

As with Thomas Jefferson or Benjamin Franklin, our Founding Fathers were not only committed to the causes of freedom but to increasing their knowledge and understanding of nature, animals and basic science.

In fact, I suspect Ben Franklin's experiments with lightening and understanding electricity would have qualified for an NSF grant.

Today, our nation is still committed to understanding the fundamentals of science. I believe that science creates the technology that drives our economic engine. As Ben Franklin stated, no nation was ever ruined by trade.

By funding science, big and small, we commit our nation to being competitive both now and in the future.

Speaking of funding, the President's budget for FY '96 calls for almost \$73 billion in Federal R&D, of which basic research is \$14.4 billion and applied and development research is \$58.4 billion.

In total R&D spending, basic research increased 3.5 percent and applied and development research decreased .5 percent.

In the FY '96 budget request, total civilian R&D increased 3.2 percent to \$34.9 billion. Civilian basic research increased 3.9 percent to \$13.2 billion. Civilian applied and development research increased 2.7 percent to \$21.6 billion.

I was pleased to note that the President made the largest percentage increase in basic research. Although I'm pleased to see the increase in basic research, I do have concerns about the approximately \$600 million increase in civilian applied and development research.

Our Subcommittee, along with others on the Science Committee, will be reviewing all these programs and will strive to manage the appropriate balance between basic and applied research.

I believe basic research, funded through merit-based peer reviewed competition results in the best research and is the best use of the taxpayers' dollar.

Within these federal R&D amounts, the National Science Foundation has requested slightly over \$3.3 billion. For those in the audience who are not familiar with the National Science Foundation, or as it is commonly referred to, NSF, it is an independent federal agency established in 1950 to promote and advance scientific progress in the United States.

NSF builds U.S. scientific strength by funding research and education activities in all fields of science and engineering.

This is accomplished at more than 2,000 colleges, universities, and other research institutions throughout the United States.

In FY '95, the NSF budget comprised approximately three percent of the federal R&D budget of \$72.7 billion. However, NSF provides about 25 percent of basic research funding at universities and over 50 percent of the federal funding for basic research in certain fields of science, including math and computer sciences, environmental sciences and the social sciences.

Moreover, NSF plays an important role in pre-college and undergraduate science and mathematics education through programs of model curriculum development, teacher preparation and enhancement, and informal science education.

The last NSF authorization, Public Law 100-570, expired at the end of FY '93.

We are extremely pleased to have before us today the Director of the National Science Foundation, Dr. Neal Lane.

Next week, this Committee will conduct a further hearing on the National Science Foundation on March 2nd. We will invite outside agency witnesses to express their opinions on the NSF budget.

However, before recognizing Dr. Lane, I would ask if the Ranking Member, the Honorable Pete Geren from Texas, or any other members present, which he has the whole row here, would like to make an opening statement.

Mr. Geren?

Mr. GEREN. Thank you, Mr. Chairman.

And I commend you on your attendance at your first Subcommittee hearing in your life chairing it. You've done an outstanding job already.

I've been sitting here trying to think of some way to match your opening statement and figure out a way to work George Washington into mine, but I cannot tell a lie; I can't do it.

[Laughter.]

Mr. GEREN. I want to also extend apologies on behalf of our end of the bench up here to Dr. Lane. You are competing with President Clinton and assuming he doesn't talk as long as he did at the State of the Union, we ought to have some of our members here to catch the tail end of your testimony.

But I appreciate very much your being here, and I know you understand the competing demands up here on the Hill.

I'm pleased to join the Chairman in welcoming you this morning, and appreciated your coming by yesterday afternoon to visit with me about many of the issues in front of us.

I'd like to make a brief opening statement. It covers some of the subjects I think are important to many of us on the Committee.

Our Committee has a long history of bipartisan support for the Foundation, due to our recognition of the important role NSF plays in developing and sustaining the academic research enterprise of the nation.

NSF's programs support research in science and engineering, the operation of national research facilities in such fields as astronomy and oceanography, the acquisition of scientific instruments and the modernization of research facilities and science education at all levels of instruction.

These wide-ranging activities underpin the technological strength of the nation through both the generation of new knowledge and the education of scientists and engineers.

The President's budget request for FY '96 provides growth for the NSF's research activities in what is otherwise a flat budget year for federal R&D.

I'm pleased to see the proposed increases for NSF's research directorates, but of course have noted that the growth is at the expense of education programs and research infrastructure-scored activities.

I will be interested to explore the rationale for the priorities which are reflected in this budget.

In particular, I'm interested in hearing your views on the appropriate level of support for the refurbishment of academic research facilities.

The NSF facilities program was devised by the Committee to address the deterioration in academic research facilities, which was highlighted by White House Science Council report in 1986 and which has been documented by NSF's periodic facility surveys.

It is naturally disappointing to see a retreat in the funding request for the facilities program after the appropriations level for FY '95 finally reached the level called for in the original authorizing legislation.

I'm aware that the National Science and Technology Council has been deliberating ways to address the facilities problem in a government-wide approach and would appreciate an update on the status of these deliberations.

Again, it's a pleasure to have you this morning, and I look forward to your testimony.

Thank you, Dr. Lane.

Mr. WAMP. Dr. Lane, feel free to use 20 minutes instead of a five-minute opening statement here. We want to hear the whole story and know that all of your comments will be placed in the record, and we look forward to hearing from you this morning.

#### **STATEMENT OF DR. NEAL LANE, DIRECTOR, NATIONAL SCIENCE FOUNDATION**

Dr. LANE. Thank you very much, Chairman Wamp, Mr. Geren.

It is an honor to participate in this very first hearing of the Basic Research Subcommittee.

I very much appreciate the opportunity to appear before you today to discuss the National Science Foundation's budget proposals for the fiscal year 1996 and our role in preparing America for the new millennium and beyond.

I appreciate your willingness to admit the written statement that will be part of the record.

In addition, I would like to ask that the Statement of the National Science Board also be included in the hearing record.

Thank you.

I'd like to believe that NSF would have supported George Washington and Benjamin Franklin, provided of course that they passed through the peer review process.

I hope that the testimony today that I'm going to give will elucidate both the philosophy of the National Science Foundation and the value of its activities to the nation.

The NSF, as you pointed out, Mr. Chairman, was established in 1950, five years after the close of the Second World War. At the

turn of the century, the year 2000, five years from now, the NSF will turn 50.

Well, as someone who is just over 50 and a proud grandfather, NSF seems quite a young institution. I assure you it is young in spirit and agile on its feet.

Nevertheless, in its short institutional life, the NSF has played a critical role in helping America establish preeminence in science and today the NSF has an important responsibility for safeguarding and enhancing the nation's scientific future.

There is general consensus among economists and policy researchers that public investment in science and engineering yield very high rates of return to society, numbers of the order 20 percent, some significantly higher, depending on the details of the study.

The activities supported by NSF, namely, fundamental research, basic research, and education based at academic institutions are generally viewed as among the most productive of all federal investments.

Mr. Chairman, we are the only federal agency mandated to promote the health of science and engineering generally, across all disciplines. And we take that responsibility very seriously.

The noted historian, Jacob Bronowski, wrote in his seminal work, *The Ascent of Man*:

"The world today is made, it is powered by science."

It was the deliberate application of science to technology on a broad scale, stimulated by World War II and the post-war years, that led policymakers, as well as scholars, to recognize science as a powerful tool in the development of society.

As you know, the creation of NSF in 1950 was largely the result of the public realization of the new value of research and development in achieving national objectives.

The NSF was charged with fostering first rate, fundamental research throughout the nation, and promoting education and training in science and engineering.

Our programs have grown from the initial small, individual project grants and fellowships to a diversity of modes of support: grants, cooperative agreements, contracts, fellowships, traineeships. We support national interagency research programs, our share of those programs. We support centers, experimental facilities, large and small, information resources, and data collection and analyses.

The Foundation has grown and has continued to evolve, in keeping with the expanding role of science and promoting economic and social progress.

The Administration's request for FY 1996 for the NSF is \$3.36 billion. As you point out, Mr. Chairman, an increase of three percent over 1995, and quite a good budget in these difficult, these tight budget times.

A summary of our fiscal year 1996 budget request is included in the written statement. The request is guided in philosophy and principle by our recently completed strategic plan, entitled "NSF In a Changing World." I believe each of you already has received a copy of this plan.

The plan sets three long-range goals for the NSF, and I'll abbreviate them as. world leadership; knowledge in service to society; and excellence in education at all levels.

Let me highlight each for just a moment, please.

World leadership in scientific research and learning does not naively assume that only America has topnotch scientists. Rather, it's a goal to articulate the need of our nation to be on the cutting edge, on the fronttier, if you like, in all important fields.

We cannot expect to win all the Nobel prizes, and we don't. But we should win many and we should aspire always to be a major player in all fields because you simply never know where the major discoveries are going to come.

Striving to attain this goal will help protect the broadest range of options of our economic and national security.

The second goal, scientific knowledge in service to society, explicitly recognizes that science is integral to life on this planet, a world very much predicated on and powered by science and technology. Thus, we cannot afford to hold science separate or autonomous from our daily lives.

Our nation, indeed every society, has real needs and problems and science must toil in those trenches as a partner in finding solutions.

Progress toward these first two goals, world leadership and knowledge and service to society, presents us with a third goal: excellence in education at all levels for a technologically literate society.

Science education in our schools should strive to make students not only science conversant but also science participatory.

Mr. Chairman, our strategic plan is an important mechanism, but translating the Foundation's vision for the future into clearcut objectives, each of our individual activities must move us toward the accomplishment of one of the three goals.

We view them as compass headings that will keep us on course.

Within this framework, I would like to describe briefly how we carry out some of our research and education activities.

As you know, NSF is the principal source of federal support for fundamental research at America's academic institutions in the science and engineering disciplines, excluding the biomedical research area where NIH has the lead.

For example, NSF supports 56 percent of the research in computer science conducted at our academic institutions, 58 percent of the research in mathematics, 43 percent of the non-medical life science research, and a high percentage of most major fields of science.

Approximately two-thirds of the Foundation's total research support is designated for individual investigators or small group research projects.

We fund the best ideas from the most qualified people as judged by their peers, experts in the fields, and competitors themselves.

It's important to appreciate that in carrying out this role, NSF helps support the underlying research enterprise that the various federal agencies and private industry depend upon to accomplish their objectives.



It's also critical for all of us to recognize that although fundamental research, by its very nature, is focused on unanswered questions that defy our ability to predict outcomes, that research is often initiated or influenced by a current practical problem.

The historical example of the French scientist Pasteur is often used to illustrate the point. Pasteur responded to public health and commercial goals throughout his stellar career in microbiology.

Both the historical record and the current record substantiate the elegant interdependence in research, the quest of new knowledge, and for pragmatic purposes.

There are numerous contemporary examples of research that is assuredly fundamental but simultaneously holds promise to address very current problems.

The study of one of nature's greatest feats of engineering, the spiderweb, may seem esoteric and fundamental—not to the spider, I would suggest, but certainly to us.

However, researchers have determined that the silk spun by the golden orb weaving spider possesses the strength of steel fibers while, at the same time, being stretchable. The process by which the spider spins silk, unlikely as it may seem, holds promise of yielding environmentally benign manufacturing techniques for industrial fibers.

This research spans the fields of biotechnology, materials and manufacturing.

Thus, when NSF funds an investigator at an academic institution, this support does not in any way imply that his or her particular research is mutually exclusive of addressing some national need or goal.

In this regard, the distinctions that we sometimes make between basic and applied research often do not exist in the real world.

Today, the Foundation has many diverse mechanisms for supporting research and education, always with the objective to create connections. Each mechanism in its own way is designed to encourage flexibility and to capitalize on the advantages of combining research and education, which is a unique characteristic of the U.S. research system.

In addition to our emphasis on individual investigators, our broad portfolio of mechanisms includes a number of centers, industry-university cooperative research centers, engineering research centers, science and technology centers, minority research centers of excellence, and long-term ecological research sites, to name only a very few.

In addition, the NSF supports the construction and operation of a number of unique and highly specialized national research facilities, such as the Gemini telescopes, the laser interferometer gravitational wave observatory, the Cornell electron storage ring, and the Cornell high energy synchrotron source, a fleet of academic research vessels and a network of astronomy observatories soon to be joined by the Gemini telescopes.

In recent years, the NSF's portfolio has evolved even further by emphasizing the special perspective and advantages of interdisciplinary fundamental research and education.

One mechanism for accomplishing this multifaceted approach is by identifying areas of national need, sometimes called strategic areas.

Let me just take a moment to explain why NSF has focused on research and education in these areas, in addition to our traditional emphasis on disciplined-based directorates.

In our 1996 budget request, we've identified seven interdisciplinary areas: advanced materials processing research, biotechnology research, civil infrastructure systems research, environment and global change research, high performance computing and communications research, manufacturing science and engineering research, and science mathematics, engineering and technology education.

We believe that also qualifies as a strategic area and certainly a multidisciplinary one.

These areas extend all across the disciplinary directorate structure of NSF.

For example, we have a directorate for mathematical and physical sciences, and we have one for biological sciences, one for geosciences, and so on.

And the Assistant Directors who run these directorates are behind me, behind me all the way.

[Laughter.]

Dr. LANE. Crosscutting areas, though, such as the strategic areas that I mentioned, provide a way to describe fundamental research and education that certainly involves the disciplines but that also requires participation of more than one discipline and that integrates knowledge across the disciplines.

The metaphor that comes to mind is that of providing a driver of an automobile with the most expansive visibility of the road. Every car has a front, side, back windows. But the driver is forced, for the most part, to look straight ahead through the windshield. At least that's a good idea.

And so cars come equipped with rearview mirrors and side view mirrors, and the mirrors provide a multi-dimensional perspective, panorama.

Clearly, you would not want to drive a car with only mirrors and no windows. But you also really wouldn't want to drive a car with only windows and no mirrors.

Our directorates at the NSF allow us to give straightforward through-the-windshield, if you like, focused attention on maintaining the health of our science and engineering disciplines; chemistry, biology, economics, electrical engineering and so forth.

Unless we advance knowledge in the disciplines, then we will not be able to address these more complex issues along multidisciplinary lines.

On the other hand, thinking of research and education only in disciplinary ways leads to a separation that, in the real world of science and engineering, does not really exist.

With only the disciplinary structure of the directorates, we miss the opportunity to glimpse the wider panorama, the territories between the disciplines and the invisible connections that bind them.

So by defining these interdisciplinary areas, such as environment and global change research, we are able to underscore the fact that

in nature, science and engineering are integrated and interwoven. That's the way the world works.

This thing gives us a panoramic vision to see and to help solve some of the problems that society faces.

Well, as I mentioned earlier, NSF is established with two primary missions: to ensure the best research in science and engineering, and to promote excellence in science, engineering, and mathematics education.

We are in fact the principal federal institution tasked with improving science and math education for all students, both K-12 and at the undergraduate level and of course at the graduate level.

We've introduced new approaches to improving mathematics, science and engineering and technology education. Our most recent initiatives are designed to create system-wide reforms at the state, city, and regional level.

We deliberately have adopted a systemic procedure to avoid fragmented changes within a single subject or within an individual school.

Our goal is to create an arc of change in which educators teach and students grasp the process and perspective of scientific thinking.

It is, after all, not the accumulation of facts that we're striving for but the acuity of judgment, analysis and problem-solving that is our ultimate educational objective.

These programs primarily come under our directorate for education and human resources, but also include activities of the other directorates as well.

Within the ten-year period from 1986 to 1996, the education and human resources directorate has received steady and rapid-funding increases. The budget in 1987 was just over \$100 million. In 1995, it's roughly \$600 million. The current figure is approximately one-fifth of the Foundation's total budget.

The increased investment we've received for EHR programs over the last ten years has allowed us to develop many new and experimental programs. And after a period of rapid growth in any program, it's important to take time for examination and evaluation.

We need to identify the strengths and the weaknesses in the programs and make improvements where they are appropriate.

Now is the time to husband further resources for these programs and use our best judgments to scrutinize them. This should not be interpreted as a sudden lack of interest or lowering our priority and our commitment to science and mathematics education. Indeed, it is 20 percent of our total budget.

I hope you will recognize this rather as an approach that reflects wisdom and watchfulness and accountability.

Although we have a separate directorate for education and human resources, we at the Foundation recognize that virtually every NSF program is, by its very nature, an educational program. Learning is what the NSF is really all about.

In a similar vein, we must be more aggressive and creative to portray education and science as useful preparation for a broad array of professional careers.

The study of science teaches us the path of critical thinking, a vehicle for informed judgment.

The study of science and engineering undergirds the fundamental elements on which much of contemporary society is built.

If Jacob Bronowski was right about the world being powered by science—I'm certainly inclined toward his view—then the usefulness of research experience is limited only by a person's imagination and drive.

In concluding my testimony, Mr. Chairman, I'd like to mention very briefly the Foundation's efforts at measuring performance.

The Government Performance and Results Act of 1993 requires each federal agency to develop a strategic plan that describes the agency's goals. And we have done such a plan.

In addition, we're required to devise methods of measuring our performance toward these goals.

Well, I must say, the process of evaluating quality is not alien to NSF. Historically, it has been at the heart of our mission and operations in choosing the best research and education projects to support.

Nevertheless, the task of developing measures to monitor our own performance in reaching our goals is a formidable challenge.

We've set up several pilot projects to road test prototype performance measures, and while it would be presumptuous to assume that our first attempts at these judgments will be on the mark in all respects, still we're working hard to find ways to try new approaches and document our progress.

Let me conclude with the wisdom of Alfred North Whitehead who said the art of progress is to preserve order amid change and to preserve change amid order.

Well, this time the change is exhilarating to the National Science Foundation and it's certainly very significant for us and for all the nation's scientists and engineers we support.

We believe we have a clearcut vision of where we need to go and an orderly path to pursue. We are taking Alfred North Whitehead's challenge to heart. We're confident in the goals we've set and we're willing for them to take us into uncharted territory because it's in that uncharted territory where the real opportunities lie.

That concludes my oral remarks, Mr. Chairman. I appreciate the time you've given me. I'd be happy to respond to any questions, and I'd like your permission to ask Deputy Director Anne Petersen to join me for the question and answers.

Mr. WAMP. That would be great. Thank you, Dr. Petersen.

[Written statement of Dr. Lane, including the National Science Foundation Budget Summary and the National Science Foundation's Strategic Plan, NSF In A Changing World, follows:]

REMARKS BY  
 DR. NEAL LANE  
 DIRECTOR, NATIONAL SCIENCE FOUNDATION  
 BEFORE THE  
 SUBCOMMITTEE ON BASIC RESEARCH  
 COMMITTEE ON SCIENCE  
 HOUSE OF REPRESENTATIVES  
 FEBRUARY 22, 1995

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Chairman Schiff, Mr. Geren, members of the subcommittee, it is an honor to be the first witness at the very first hearing of the Basic Research Subcommittee. Mr. Schiff, congratulations on your Chairmanship. I very much appreciate the opportunity to appear before you today to discuss the National Science Foundation's budget proposals for fiscal year 1996 and our role in preparing America for the new millennium and beyond.

A CONTEXT FOR THE NATIONAL SCIENCE FOUNDATION

I hope that my testimony today will elucidate both the philosophy and the value of the activities of the National Science Foundation to the nation. The NSF was established in 1950, 5 years after the close of the Second World War. At the turn of this century, in the year 2000, just five years from now, the NSF will turn 50. As someone who is a bit older than 50 and a grandfather, the NSF seems to me quite a young institution. It is certainly young in spirit.

Nevertheless, in its short institutional life, the NSF has played a critical role in helping America establish preeminence in science. Today, the NSF has an important responsibility for safeguarding and enhancing the nation's scientific future.

There is general consensus among economists and policy researchers that public investments in science and engineering yield very high annual rates of return to society (i.e., well over 20 percent). At a recent conference conducted jointly by the American Enterprise Institute and the Brookings Institution, many top researchers, including former Council of Economic Advisers Chairs Michael Boskin and Charles Schultze, agreed that research and development have a significant and important positive effect on economic growth and living standards. Furthermore, the activities supported by the NSF — namely fundamental research and education based at academic institutions — are generally viewed as among the most productive of all federal investments.

Mr. Chairman, we are the only federal agency mandated to promote the health of science and engineering generally across all disciplines. We take that responsibility very seriously.

The noted historian, Jacob Bronowski, wrote in his seminal work, *The Ascent of Man*, (quote) "The world today is made, it is powered by science." (end quote) It was the deliberate application of science to technology on a broad scale, stimulated by World War II and the post-war years, that led policy makers as well as scholars to recognize science as a powerful tool in the development of society.

This is not to say that science was irrelevant to the intellectual, industrial, or cultural life of civilization previously. The science curve began several millennia before the birth of Christ. And we all learned in school about the great achievements of the Greeks in advancing scientific thought. It is clear, however, that the war and the broad technological expansion after the war placed science in a new and central role in our society, fueling economic development and improving health and well-being.

As all of you know, the creation of the NSF in 1950 was largely the result of public realization of this new value of research and development in achieving national objectives. The NSF was charged with fostering first-rate fundamental research throughout the nation, and promoting education and training in science and engineering.

A dramatic turning point for the NSF and the nation occurred in 1957 with the Soviet launch of Sputnik. Suddenly, America felt an impending threat of Soviet supremacy in science and technology. The Congress responded with the Space Act in 1958, the creation of the National Aeronautics and Space Administration, and the establishment of this Committee, under the old name Science and Astronautics, in 1959.

Sputnik moved the NSF's mission into more aggressive focus with a national call for improving scientific education and expanding scientific research. To put this change into graphic relief, the very first appropriation for the NSF, in 1951, was \$225,000. By 1966, that funding figure had grown to \$480 million. Our programs had grown from the initial, small individual project grants and fellowships to a diversity of grants, contracts, fellowships, traineeships, national research programs, information resources, and data collection and analysis.

The NSF has continued to grow and evolve, in keeping with the expanding role of science in promoting economic and social progress. Our national goals, including business and commerce, have become dependent on ever more sophisticated science and technology. Science and technology have become increasingly intertwined, each benefiting from the other in complex ways. Universities, industry, and government have learned the advantages of collaboration and partnership.

#### NSF'S INVESTMENT STRATEGY

Today, the Administration's request for FY 1996 for the NSF is \$3.36 billion. A summary of our fiscal year 1996 budget request is included at the end of this statement.

Our budget request is guided in philosophy and principle by our recently completed Strategic Plan, entitled, *NSF in a Changing World*. I believe each of you has already received a copy.

The Plan sets three long-range goals for the NSF which I will abbreviate as:

- world leadership
- knowledge in service to society
- achieving excellence in education at all levels

Let me highlight each for a moment. World leadership in scientific research and learning does not naively assume that only America has top-notch scientists. Rather, it is a goal to articulate the need for our nation to be on the cutting-edge, the frontier, in all important fields. We cannot expect to win all the Nobel prizes, but we should win many. And we should aspire always to be a major player in all fields because you never know where the discoveries will occur. Striving to attain this goal will help protect the broadest range of options for our economic and national security.

The second goal, scientific knowledge in service to society recognizes that science is integral to life on this planet, a world very much predicated on and powered by science and technology. Thus we cannot afford to hold science separate and autonomous from our daily lives. Our nation, indeed every society, has real needs and problems. Science must toil in those trenches as a partner in finding solutions.

Progress toward these first two goals – world leadership, and knowledge in service to society – presents us with the third goal, excellence in education at all levels for a technologically literate society. Science education in our schools should strive to make students not only science conversant, but also science participatory. If there is any sure-fire way to INTEGRATE SCIENCE INTO SOCIETY it is to build science confidence in young people through their own experimentation, analysis, and questioning.

Mr. Chairman, our Strategic Plan is an important mechanism for translating the Foundation's vision for the future into clear-cut objectives. Each of our individual activities must move us toward the accomplishment of one of the three goals. We view them as compass headings that will keep us on course.

Within this framework, I would like to elaborate on how we carry out some of our research and education activities.

#### SUPPORT FOR RESEARCH AND EDUCATION

As you well know, NSF is the principal source of federal support for fundamental research at America's academic institutions in the science and engineering disciplines (excluding biomedical science where NIH has the lead). For example, we support 56 percent of the research in computer science conducted at our academic institutions, and 43 percent of the non-medical life science research.

Approximately two thirds of the Foundation's total research support is designated for individual investigators or small group research projects. We fund the best ideas from the most qualified people – as judged by their peers, experts in the field – while nurturing future generations of scientists and engineers. It is important to appreciate that in carrying out this role, the NSF helps support the underlying research enterprise that the various Federal agencies and private industry depend upon to accomplish their objectives.

It is also critical for all of us to recognize that although fundamental research, by its very nature, is focused on the unanswered questions that defy our ability to predict outcomes, that research is often initiated or influenced by a current, practical problem. The historical example of the French scientist Pasteur is often used to illustrate this point. Pasteur responded to public health and commercial goals throughout his stellar career in microbiology. Both the historical record and the current record substantiate the elegant interdependence in research of the quest for new knowledge and pragmatic purposes.

There are numerous contemporary examples of research that is assuredly fundamental but simultaneously holds promise to address very current problems. The study of one of nature's greatest feats of engineering, the spider web, may seem to be esoteric and fundamental. However, researchers have determined that the silk spun by the golden orb-weaving spider possesses the strength of steel fibers while also being stretchable. The process by which a spider spins silk, unlikely as it may seem, holds promise of yielding environmentally-benign manufacturing techniques for industrial fibers. This research spans[no pun intended] the fields of biotechnology, materials, and manufacturing.

Thus, when the NSF funds an investigator at an academic institution, this support does not in any way imply that his or her particular research is mutually exclusive of addressing some national need or goal. On the contrary, the distinctions that we make between basic and applied research with our words and definitions often do not exist in the world of science and engineering.

It is clear that all federally supported researchers want to be doing important work. Many things go into their determination of what is important, including knowledge of the frontiers of their fields and an awareness of how their work might be used.

## A BALANCED PORTFOLIO

Today, the Foundation has many diverse mechanisms for supporting research and education, always with the objective to create connections. Each mechanism, in its own way, is designed to encourage flexibility and to capitalize on the advantages of combining research and education, which is a unique characteristic of the U.S. research system. Our broad portfolio of mechanisms includes individual investigators, small groups, Industry-University Cooperative Research Centers, Engineering Research Centers, Science and Technology Centers, Minority Research Centers of Excellence, and Long Term Ecological Research sites to name a few.

In addition, the NSF supports the construction and operation of a number of unique and highly specialized national research facilities such as the GEMINI telescope, the Laser Interferometer Gravitational Wave Observatory (LIGO), the Cornell Electron Storage Ring/ Cornell High Energy Synchrotron Source, a fleet of academic research vessels, and a network of astronomy centers.

These centers and national facilities are designed to address an identified need in a flexible and comprehensive institutional setting. The goal is always to bring a creative combination of resources and personnel to bear on a problem.

The various NSF research centers and national facilities, along with the long established individual investigator awards, reflect the flexibility of our research support mechanisms. In recent years, the NSF's portfolio has evolved even further by emphasizing the special perspective and advantages of interdisciplinary fundamental research and education. One mechanism for accomplishing this multifaceted approach is by identifying areas of national need, sometimes called "strategic" areas.

These build on our traditional Directorates and have strengthened the flexibility of our research and education support mechanisms to meet the changing needs of our economy, and the society in general.

Let me take a moment to explain why NSF has focused on research and education in these areas, in addition to our traditional emphasis on the discipline-based Directorates.

In our FY 1996 budget request, we have identified seven interdisciplinary areas:

- Advanced Materials and Processing research
- Biotechnology research
- Civil Infrastructure Systems research
- Environment and Global Change research
- High Performance Computing and Communications research
- Manufacturing Science and Engineering research, and
- Science, Math, Engineering, and Technology Education

These areas extend across the directorate structure of the NSF, which tracks with traditional disciplinary lines. For example, we have a directorate for mathematical and physical sciences,



one for biological sciences, one for geosciences, and so on. Cross-cutting areas provide a way to support fundamental research and education that requires participation of more than one discipline.

The metaphor that comes to mind for this objective is that of providing the driver of an automobile with the most expansive visibility of activity on the road surrounding him or her. Every car has front, side, and back windows. But the driver is forced, for the most part, to look straight ahead. And so, cars come equipped with a rearview mirror and sideview mirrors.

The mirrors provide the driver with a multi-dimensional perspective. They give a panoramic view, in addition to the more confined view out of any window. Just as you would not want to drive a car with only windows for visibility, you also would not want to drive a car with only mirrors and no windows.

Our Directorates at the NSF allow us to give straightforward, focused attention to maintaining the health of our science and engineering disciplines. Unless we advance knowledge in the disciplines, we will not be able to address complex issues along multi-disciplinary lines. On the other hand, thinking of research and education in only disciplinary ways leads to a separation that, in the real world of science and engineering, does not exist. With only the structure of the Directorates, we lose the opportunity to glimpse the territories between them and the invisible connections that bind them.

By using interdisciplinary areas, we are able to understand and explore the world of science and engineering as integrated and interwoven -- the way in which it really works. This gives us the panoramic opportunities to see and solve problems in cross-cutting approaches.

## EDUCATION AND HUMAN RESOURCES

As I mentioned earlier, the NSF was established with two primary missions -- to insure the best research in science and engineering, and to promote excellence in science, engineering, and mathematics education. We are, in fact, a principal federal institution tasked with improving science and math education for all students, both K-12 and at the undergraduate level, and of course at the graduate level. By building strong science, engineering, and math skills for all students throughout their school careers, we assure the nation a technologically literate 21st century workforce to compete in the global marketplace.

We have introduced new approaches to improving mathematics, science, engineering, and technology education. Our most recent initiatives are designed to create system-wide reforms at state, city, and regional levels. We deliberately have adopted a systemic procedure to avoid fragmented changes within a single subject matter or an individual school.

Our goal is to create an arc of change within which educators teach and students grasp the process and perspective of scientific thinking. It is, after all, not the accumulation of facts that we are striving for but rather the acuity of judgment, analysis, and problem-solving that is our ultimate educational objective.

In recognition of the different educational environments that exist within our vast nation, we have not proclaimed that one systemic arrangement "fits all." We have state-wide, urban, and rural systemic initiatives to accommodate the unique and variable environments in which education takes place across the country.

These programs primarily come under our Directorate for Education and Human Resources (EHR). Within the 10 year period from 1986 - 1996, the Education and Human Resources Directorate has received steady and rapid funding increases. The budget in 1987 was just over

\$100 million; in 1995 it is roughly \$600 million. The current figure is approximately one-fifth of the Foundation's total budget.

The increased investment we have received for EHR programs over the last 10 years has allowed us to develop many new and experimental programs. After a period of rapid growth in any program, there is a concomitantly important time for examination and evaluation. We need to identify strengths and weaknesses in the programs in order to make improvements.

Now is the time to husband further resources for these programs and harness our best judgment to scrutinize them. That is why you will see a distinct funding plateau for this year's request. Actually, there is a slight decline. This should not be interpreted as a sudden lack of interest or priority in our commitment to science and math education. I hope you will recognize this trend as wisdom and watchfulness.

Our goal is to assure that every child is prepared to take science and math understanding and skills from school into life, into the workplace, into the community, and into their personal portfolios for success.

As an economically prosperous and competitive nation, we cannot afford to lose a single child's contribution. As a compassionate nation, we cannot neglect a single child's opportunity to learn and to live up to his or her highest potential.

Mr. Chairman, the federal government cannot teach a single child but we can help make it possible for every child to learn. We can leverage resources and promote reform. We can share responsibility and we can offer opportunity. The NSF is committed to being a steadfast partner with the states, the cities, parents, teachers, administrators, students and citizens to accomplish this task.

#### LINKING DISCOVERY AND LEARNING

Although we have a separate Directorate for Education and Human Resources, we at the Foundation recognize that virtually every NSF program is, by its very nature, an educational program as well. We must be even more alert to the myriad opportunities for capitalizing on the natural connections between the process of education and that of discovery.

In a similar vein, we must be more aggressive and creative to portray training in science as useful preparation for a broad array of professional careers. The study of science teaches us the path of critical thinking — a vehicle for informed judgment. We live in a world where informed judgment seems to be in short supply.

I believe we should be encouraging our students to broaden their understanding and expectations of the diverse usefulness of their knowledge. After all, the study of science and engineering undergirds the fundamental elements on which much of contemporary society is built. The study of science and engineering arms students with the knowledge and skills to be captains of industry, leaders in government, editors of newspapers, film producers, or stock brokers to name a few possibilities.

If Jacob Bronowski was right about the world being powered by science, and I think he was, then the usefulness of research training is limited only by a person's imagination, not by the society in which he or she lives. Those in government and in the universities have a responsibility to articulate this philosophy. After all, we are partly at fault for defining science and engineering as esoteric and separate, when in fact it is universal and pervasive.

## CONCLUSION

In concluding my testimony, I would like to mention briefly the Foundation's efforts at measuring performance. The Government Performance and Results Act of 1993 requires each federal agency to develop a strategic plan that describes the agency's goals. In addition, we are required to devise methods of measuring our performance toward those goals.

At the same time, as part of the President's Reinventing Government Initiative, all federal agencies are reexamining their missions. This includes: addressing the mission based on "customer" input; asking whether the mission could be accomplished as well or better without federal involvement; looking for ways to cut costs or improve performance through competition; and ways to put customers first, cut red tape, and empower employees. We are actively participating in this effort and will keep you fully apprised of our review.

I must say that the process of evaluating quality is not alien to the NSF. Historically, it has been at the heart of our mission and operation in choosing the best research to support.

Nevertheless, the task of developing measures to monitor our own performance in reaching our goals is a formidable challenge. We have set up several pilot projects to road-test prototype performance measures. It would be presumptuous to assume that our first attempts at these judgments will be on-the-mark in all respects. In fact, if we jump to the conclusion that they are perfect, we are likely missing the point by a large margin. But we are working hard to find ways to document our progress.

Let me conclude with the wisdom of Alfred North Whitehead who said, (quote) "The art of progress is to preserve order amid change and to preserve change amid order." (end quote)

This time of change is exhilarating for the National Science Foundation. It is significant for us, and for all the nation's institutions. We believe we have a clear-cut vision of where we need to go, an orderly path to pursue. We are confident in the goals we have set and are willing for them to take us into uncharted territory and new opportunity. We are taking Alfred North Whitehead's challenge to heart.

Thank you for this opportunity to appear before this Subcommittee. I would be pleased to answer any questions you may have.

## SUMMARY OF THE FY 1996 NSF BUDGET BY APPROPRIATION ACCOUNT

### Research and Related Activities

The FY 1996 Budget Request for the Research and Related Activities (R&RA) Appropriation is \$2,454.00 million, an increase of \$174.00 million, or 7.6 percent, over the FY 1995 Current Plan of \$2,280.00 million. The R&RA Appropriation supports activities that enable the United States to uphold world leadership in all aspects of science and engineering, and to promote the discovery, integration, dissemination and employment of new knowledge in service to society. Research activities contribute to the achievement of these goals through expansion of the knowledge base; integration of research and education; stimulation of knowledge transfer among academia and the public and private sectors; and bringing the perspectives of many disciplines to bear on complex problems important to the nation.

Merit review is the principal tool in selecting among proposals for funding. Review emphasizes the capabilities of the investigators, the innovation, importance and relevance of the ideas and approaches, and the potential for enhancing the human and physical infrastructure of science and engineering.

A summary of the Activities within R&RA follows:

The Biological Sciences (BIO) Activity fosters understanding of the underlying principles and mechanisms governing life. Research ranges from the study of the structure and dynamics of biological molecules, such as proteins and nucleic acids, through cells, organs and organisms, to studies of populations and ecosystems. It encompasses processes that are internal to the organism as well as those that are external, and includes temporal frameworks ranging from measurements in real time through individual life spans, to the full scope of evolutionary time. The 7.6 percent increase, to a total of \$323.96 million in FY 1996, will primarily support research in biotechnology, biodiversity, and terrestrial ecology related to global change.

Research in the Computer and Information Science and Engineering (CISE) Activity includes system software design, theory of computing, engineering design, prototyping, testing, and deployment of cutting-edge computing and communications systems to address complex research problems. The 6.7 percent increase, to a total of \$275.57 million in FY 1996, is principally directed toward research in ubiquitous computing, human-machine interaction and information access, parallel and distributed computing, and toward multidisciplinary challenges -- laying the groundwork for future information technology that can help solve complex computational and communications intensive problems of scientific and societal importance. Additional experimental high-speed networking activities will be supported. The Supercomputer Centers will initiate new cooperative activities with other high performance computation facilities nationwide, and their computational infrastructure will be enhanced to carry out leading edge research.

The Engineering (ENG) Activity seeks to enhance long-term economic strength, security, and quality of life for the nation by fostering innovation, creativity, and excellence in engineering education and research. ENG seeks to promote the natural synergy between engineering education, fundamental research, and the application of technical knowledge. The ENG Activity's 7.7 percent increase, to a total of \$344.16 million for FY 1996, will primarily go to support research in areas such as intelligent sensing and control systems and environmentally conscious manufacturing. Funds are included to meet the mandated level for the Foundation-wide Small

Business Innovation Research (SBIR) program and the authorized level for the Small Business Technology Transfer (STTR) program.

The Geosciences (GEO) Activity supports research in the atmospheric, earth, and ocean sciences. Basic research in the geosciences advances the scientific knowledge of the Earth's environment, including resources such as water, energy, minerals, biological diversity, and coral reefs. GEO supported research also advances the ability to predict natural phenomena of economic and human significance, such as climate changes, weather, earthquakes, fish-stock fluctuations, and disruptive events in the solar-terrestrial environment. The 7.6 percent increase, to \$451.48 million in FY 1996, will support fundamental research and national user facilities across the geosciences, including new and enhanced efforts in international programs, forecasting and climate modeling, and studies of continent-ocean margins.

The Mathematical and Physical Sciences (MPS) Activity supports research in mathematics, astronomy, physics, chemistry, and materials science. Major equipment and instrumentation such as particle accelerators and telescopes are provided to support the research needs of individual investigators. The 8.3 percent increase, to \$698.28 million in FY 1996, will be directed to areas including multidisciplinary research in optical science and engineering, environmental science and technology, biotechnology, nanosciences, and will enhance support for facilities and instrumentation.

The Social, Behavioral and Economic Sciences (SBE) Activity stimulates scientific progress in these fields. Research focuses on how various social and economic systems are organized and operate, and how cognitive and cultural factors influence human behavior. Activities include the Human Capital Initiative and a consortium for research on violence to be initiated in FY 1995. The Activity also includes programs that promote international scientific cooperation and provide authoritative data on science and engineering and the characteristics of the nation's research and education enterprise. The 8.0 percent increase, to \$122.87 million in FY 1996, will support research on human genetic diversity, learning and intelligent systems, and research on democratic processes.

Polar Programs, which includes the U.S. Polar Research Programs and U.S. Antarctic Logistical Support Activities, supports multi-disciplinary research in Arctic and Antarctic regions. Polar regions play a critical role in world weather and climate and provide unique research opportunities in environmental sciences, ranging from the ocean bottom, through the ice layer, and into space. The 6.1 percent increase in Polar Programs, to \$234.88 million, will be directed entirely to U.S. Polar Research Programs. Priority is given to increases for arctic research, including Arctic logistics. Increases are also provided for studies of the oceans surrounding Antarctica, research on Antarctic ice sheets, and for science facilities and operations that make Antarctic research possible.

The Critical Technologies Institute is a Federally-Funded Research and Development Center that provides analytical support to the Office of Science and Technology Policy by identifying near-term and long-term objectives for research and development; analyzing the production capability and economic viability of technologies; and providing options for achieving R&D objectives.

#### Education and Human Resources

The FY 1996 Budget Request for Education and Human Resources (EHR) is \$599.00 million, a decrease of \$6.97 million, or 1.2 percent, from the FY 1995 Current Plan of \$605.97 million. EHR supports a cohesive and comprehensive set of activities, augmented by informal science experiences, which encompass every level of education and every region of the country. EHR is a major participant in interagency efforts for science, mathematics, engineering and technology

education (SMETE) initiative, totaling \$530.88 million in FY 1996. This initiative addresses many of the challenges posed by *Goals 2000: Educate America Act*.

- Support at the K-12 level totals \$354.78 million, a decrease of \$810,000 from the FY 1995 Current Plan. This support is focused primarily in the Systemic Reform activities (\$95.35 million) in states, urban, and rural areas, and Elementary, Secondary and Informal Science activities that enable all students to achieve in science, mathematics, engineering and technology education.
- Support at the Undergraduate level is \$102.50 million, a decrease of \$640,000 from the FY 1995 Current Plan. This support is focused primarily on improving undergraduate preparation of K-12 teachers and addressing advanced technician training. Efforts of reforming curriculum and laboratory instruction, and upgrading equipment continue to be major emphases.
- Support at the Graduate level is \$67.50 million, unchanged from the FY 1995 level. This support maintains the modest increases in both the stipend and the cost of education allowance provided in FY 1995 for the Graduate Fellowship program. The number of fellows will remain at approximately 2,400. The Graduate Research Traineeship program will be sustained at the FY 1995 level to maintain support for ongoing projects. No new traineeship positions are planned.
- Advanced Technological Education (ATE) established in FY 1994, is \$23.35 million, unchanged from the FY 1995 level. Support will continue to focus on improving curriculum development and program improvement at the secondary and undergraduate levels to help transition students to the increasingly technology-based workforce.

#### Academic Research Infrastructure

The FY 1996 Budget Request for the Academic Research Infrastructure (ARI) Activity is \$100 million, a decrease of \$18.13 million, or 15.3 percent, from the FY 1995 Current Plan of 118.13 million.

The FY 1995 Appropriation originally included \$118.13 million for NSF's Academic Research Infrastructure Activity, and an additional \$131.87 million for an interagency infrastructure program, for a total appropriation of \$250 million. The availability of funds for an interagency program is contingent on the development of an interagency program for FY 1996. The Administration has elected not to initiate such a program and has proposed rescission of the \$131.87 million, resulting in an FY 1995 Current Plan of \$118.13 million.

In FY 1996, NSF is requesting \$100 million for Academic Research Infrastructure, which will be equally divided between facilities and instrumentation. This represents an increase of 81.8 percent over the FY 1995 Request of \$55 million. NSF believes that \$100 million will provide for continued progress on renewal of these important research resources while maintaining an appropriate balance between support for research activities and infrastructure.

#### Major Research Equipment

The FY 1996 Request for the Major Research Equipment (MRE) appropriation is \$70 million. MRE was established in FY 1995 to support construction of major research facilities that provide unique capabilities at the cutting edge of science and engineering. The FY 1996 request of \$70

million represents a \$56 million decrease, or -44.4 percent, below the FY 1995 level for these items.

Projects supported by this Account will push the boundaries of technology and will offer significant expansion of opportunities, frequently in totally new directions, for the science and engineering community. Two projects currently comprise the Major Research Equipment Account: the Laser Interferometer Gravitational Wave Observatory (LIGO) and the Gemini telescopes, twin eight-meter telescopes in the northern and southern hemispheres, being built through an international partnership. Per Congressional action, \$35 million made available for LIGO in FY 1994 within the Research and Related Activities account was rescinded. This \$35 million was restored for LIGO in the FY 1995 MRE account, with an additional \$50 million requested. This brings the FY 1995 total funding for LIGO to \$85 million. Also, in addition to the FY 1995 request of \$20 million for the Gemini telescopes, Congress appropriated another \$21 million, for a total of \$41 million in FY 1995. Funding for construction of the Gemini telescopes was completed in FY 1995. No additional funds will be requested for construction of the Gemini telescopes in FY 1996.

The \$70 million request in FY 1996 will permit the LIGO project to progress toward completion of construction in FY 1998 and a transition to operations during FY 1999.

#### Salaries and Expenses

The FY 1996 Request for Salaries and Expenses (S&E) is \$127.31 million, an increase of \$3.34 million, or 2.7 percent, over the FY 1995 Current Plan level of \$123.97 million. The Request level supports an authorized ceiling of 1,226 full-time equivalents (FTEs), provides for current administrative levels, and continues the investment in information technology for administrative processes.

Salaries and Expenses provides funds for staff salaries and benefits, and general operating expenses necessary to manage and administer the NSF. Funds are requested separately for FTEs and direct expenses of the Office of Inspector General and for NSF Headquarters Relocation, the appropriation account which includes funds to reimburse the General Services Administration (GSA) for expenses incurred to relocate the Foundation to its new Headquarters location in Arlington, Virginia.

#### NSF Headquarters Relocation

The FY 1996 Request for NSF Headquarters Relocation is \$5.20 million, equal to the FY 1995 level. This appropriation account provides annual reimbursement to the General Services Administration (GSA) through FY 1999 for expenses incurred by GSA pursuant to the relocation of the National Science Headquarters to Arlington, Virginia, which was completed in January 1994.

#### Office of Inspector General

The Office of Inspector General (OIG) was established to promote economy, efficiency, and effectiveness in administering the Foundation's programs; to detect and prevent fraud, waste, or abuse within NSF or by individuals that request or receive NSF funding; and to identify and resolve cases of misconduct in science. The FY 1996 Request for the OIG is \$4.49 million, an increase of \$0.11 million over the FY 1995 Current Plan.

# **National Science Foundation**

## **BUDGET SUMMARY**

**Fiscal Year 1996**





**National Science Foundation  
Fiscal Year 1996 Budget Request  
Overview**



**FY 1996 Request      =      \$3,360 million**

NSF's investments in research and education strengthen and help secure the nation's capability to excel in science and engineering. As a principal supporter of fundamental research conducted at colleges and universities and of mathematics, science, and engineering education, NSF helps to provide the nation with both the base of advanced knowledge and the highly skilled workforce needed to pursue and capitalize on opportunities in science and technology.

NSF's FY 1996 request is shown in Figure 1

**The Return on Investments in NSF**

There is general consensus among economists and policy researchers that public investments in science and engineering yield very high annual rates of return to society (i.e., well over 20 percent). At a recent conference conducted jointly by the American Enterprise Institute and the Brookings Institution, many top researchers, including former Council of Economic Advisers Chairs Michael Boskin and Charles Schultze, agreed that research and development has a significant and important positive effect on economic growth and living standards. Furthermore, the activities supported by NSF -- namely fundamental research and education based at academic institutions -- are generally viewed as among the most productive of all Federal investments.

Figure 1

**NSF FY 1996 Budget Request**  
(Dollars in Millions)

	FY 1995 Plan	FY 1996 Request	Change	
			Amount	Percent
Research & Related Activities <sup>1</sup>	2,280 00	2,454 00	174 00	7 6%
Education & Human Resources	605 97	599 00	(6 97)	-1 2%
Academic Research Infrastructure <sup>2</sup>	118 13	100 00	(18 13)	-15 3%
Major Research Equipment <sup>1</sup>	126 00	70 00	(56 00)	-44 4%
Salaries & Expenses	123 97	127 31	3 34	2 7%
NSF Headquarters Relocation	5 20	5 20	0 00	0 0%
Office of Inspector General	4 38	4 49	0 11	2 5%
<b>Total, NSF<sup>1</sup></b>	<b>\$3,263 65</b>	<b>\$3,360 00</b>	<b>\$96 35</b>	<b>3 0%</b>

<sup>1</sup> \$35 million available for LIGO in FY 1994 within R&RA was rescinded and restored in the FY 1995 plan within MRE.

<sup>2</sup> Total new budget authority for NSF in FY 1995 is \$3 228 billion.

<sup>3</sup> Assumes proposed rescission of \$131 87 million in ARI.

In recent years, NSF's investments have enabled numerous important advances that have extended the frontiers of knowledge, contributed to addressing many of the nation's most pressing concerns and priorities, and provided education and training opportunities for the science and engineering workforce.

- NSF has worked in partnership with NASA and other organizations to support research on the collision between Comet Shoemaker-Levy 9 and Jupiter. Researchers using NSF-supported supercomputing resources predicted the time and place of the individual collisions. Images of the impacts have been made widely available via electronic networks to researchers, teachers, and the general public. Astronomers and planetary scientists supported by NSF and NASA continue to analyze data from the collisions to determine the long-term effects on Jupiter's atmosphere and structure as well as how such collisions might have influenced the Earth's development.
- Micro-electromechanical systems (MEMS) -- mixtures of sensors, motors, and computers that can fit on the head of a pin -- have emerged as a valuable commercial technology thanks in large part to NSF's timely support of fundamental research. The current market for MEMS devices is estimated to exceed \$1 billion, and the automobile industry now uses MEMS devices in airbags and electronic ignition systems. Support provided through NSF's engineering activities led to the first micro-motors and other crucial advances.
- NSF's leadership in mathematics, science, engineering, and technology education has enabled 25 states, 25 urban areas, six rural regions, and scores of colleges and universities to plan for and, in many instances, initiate total system reform efforts. These efforts are based on the premise that all students can achieve at much higher levels than at present.
- Research in mathematical economics supported by NSF has yielded new insights into the dynamics of competition in the marketplace. The Federal Communications Commission

drew upon these insights when designing the auctions to allocate licenses for use of the electromagnetic spectrum -- auctions that have netted billions of dollars to the U.S. Treasury.

Through its FY 1996 budget request, NSF will continue to seek the most promising and highest quality investments in research and education. The roughly 20,000 projects NSF supports annually are selected strictly on the basis of merit and cover all disciplines of the sciences and engineering and all levels of education. The research and education community has direct input into NSF's funding decisions; this year, for example, over 60,000 researchers and educators are expected to participate in the process of reviewing proposals submitted to the Foundation.

In addition, NSF employs a variety of mechanisms to increase the return on the nation's investments in research and education -- including fostering industry/university/government partnerships and state/Federal partnerships in research and education, supporting multidisciplinary approaches to solving complex problems, participating in interagency activities coordinated by the National Science and Technology Council, and promoting international cooperation and cost-sharing.

### **NSF's Investment Goals**

The Administration's August 1994 report, *Science in the National Interest*, outlined a policy framework for all Federal investments in fundamental science, mathematics, and engineering. The report stressed that "America's future demands investment in our people, institutions, and ideas. Science is an essential part of this investment, an endless and sustainable resource with extraordinary dividends."

Consistent with the Administration's policy framework, the NSF has developed a strategic plan that was endorsed by the National Science Board in October of 1994. The plan identifies a course of action in keeping with the Foundation's long-standing tradition of excellence and its commitment to working in partnership with other organizations dedicated to advancing science and engineering.

The plan sets forth three broad goals to help guide the agency's investments:

- Enable the United States to uphold a position of world leadership in science, mathematics, and engineering.
- Promote the discovery, integration, dissemination, and employment of new knowledge in service to society.
- Achieve excellence in U.S. science, mathematics, engineering, and technology education at all levels.

*Upholding World Leadership.* NSF's first goal -- enable the United States to uphold a position of world leadership in science, mathematics, and engineering -- serves as the agency's capstone goal. NSF's programs are essential to upholding U.S. world leadership because they sustain what is truly the nucleus of the nation's scientific enterprise -- basic research conducted

at academic institutions and education in engineering and the sciences. This support produces both the new knowledge and the talented people that enable the U.S. to realize opportunities in science and technology.

While NSF accounts for only 3 percent of total Federal spending for R&D, it provides nearly one-half of all Federal support for non-medical basic research performed by colleges and universities, and roughly 30 percent of total Federal support for science, mathematics, engineering, and technology education. Furthermore, in many core scientific disciplines, such as physics, chemistry, computer science, mathematics, biology, and the geosciences, NSF is the dominant source of Federal support for university basic research, as Figure 2 illustrates.

Figure 2

**Upholding World Leadership**  
NSF Share of Total Federal Support for Basic Research at Academic Institutions  
and for Mathematics and Science Education

Discipline	Share of Federal Support
Social Sciences	61%
Mathematics	58%
Computer Science	56%
Geosciences	51%
Biological Sciences (Non-Medical)	43%
Physical Sciences	42%
Engineering	33%
Science, Mathematics, Engineering & Technology Education	30%
NSF Share of Total Federal R&D	3%

NSF's FY 1996 request includes a balanced set of investments that will help uphold the agency's leadership role in fundamental research and education. The Foundation's request for Research and Related Activities would increase by 8 percent over the 1995 level to a total of \$2,454 million. NSF is also seeking nearly \$600 million for its Education and Human Resources activity, \$70 million for Major Research Equipment, and \$100 million for investments in Academic Research Infrastructure.

*Knowledge In Service to Society.* NSF employs a variety of mechanisms that help all Americans reap the benefits resulting from advances in science and engineering, in keeping with the agency's second goal of advancing knowledge in service to society. In recent years, NSF has increased its emphasis on industry/academe partnerships to improve knowledge transfer between the different sectors and better prepare students of science and engineering for careers in industry and government. NSF's support for advanced computing and networking has helped make tools and resources such as the Internet and the World Wide Web available to anyone with a personal computer.

Another mechanism NSF employs to promote the discovery and integration of knowledge in service to society is the support of research and education in strategic areas of national priority.

In FY 1996, nearly two-thirds of the agency's support for fundamental research and education can be related to seven broadly-defined areas where advances in fundamental research and education are necessary to address key challenges facing the nation. These areas include the Advanced Materials and Processing Program, Biotechnology, Civil Infrastructure Systems, Environment and Global Change, High Performance Computing and Communications, Manufacturing, and Science, Mathematics, Engineering, and Technology Education. As is shown in Figure 3, NSF expects to increase its total investment in these areas by more than \$85 million in FY 1996. NSF works closely with other Federal agencies to define priorities in these areas.

Figure 3

**Basic Research and Education in Interdisciplinary Strategic Areas**  
(Millions of Dollars)

	FY 1995 Estimate	FY 1996 Estimate	Percent Change
Advanced Materials & Processing Program	\$213	\$226	6.0%
Biotechnology	\$166	\$177	6.2%
Civil Infrastructure Systems	\$55	\$57	5.1%
Environment & Global Change	\$329	\$356	7.9%
High Performance Computing & Communications	\$297	\$314	5.6%
Manufacturing	\$128	\$136	6.2%
Science, Math, Engineering & Technology Education	\$647	\$656	1.4%

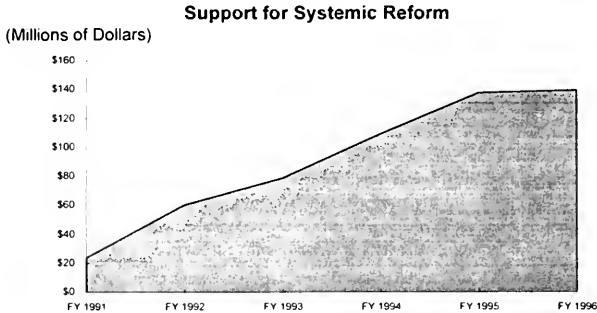
NSF also gives special emphasis to emerging areas of science and engineering that show great promise for advancing fundamental knowledge and for spurring economic and social progress. In this budget request, areas receiving additional focus include optical science and engineering, environmentally conscious design and manufacturing, the development of human capital, research on water and watersheds, and arctic research.

*Achieving Excellence in Education.* To achieve excellence in U.S. science, mathematics, engineering, and technology education, NSF supports programs at all educational levels -- from preschool to the postgraduate level. These programs aim to engage all students in science -- not just those who will become scientists, engineers, technicians, and teachers -- so that they can gain the scientific and technological literacy needed to function and prosper in our increasingly technology-based society. These programs also place great emphasis on evaluation in order to track their progress and identify promising projects for widespread dissemination.

As is shown in Figure 4, over the past five years NSF has greatly increased its investment in a number of systemic reform activities that foster comprehensive change at the city, state, regional, and national level. The underlying premise of these activities is that to attain world class standards in mathematics and science education, we must replace isolated and piecemeal reform efforts with more ambitious, coordinated approaches that involve many aspects of the system. The potential impact of this approach has become apparent. Less than five years ago, for example, NSF began supporting a national effort to reform the teaching of calculus. One of the major projects under this effort began as a consortium of eight institutions,

but the materials developed through it are now in use on over 300 campuses and reach over 20% of the undergraduate students enrolled in introductory calculus.

Figure 4



### Core Programmatic Strategies

To help reach each of its three goals, the NSF has identified four core strategies for its programs in research and education:

- Develop Intellectual Capital
- Strengthen the Physical Infrastructure
- Integrate Research and Education
- Promote Partnerships

These four strategies provide specific direction for NSF's proposed investments to help realize the agency's long-term goals.

*Develop Intellectual Capital.* Virtually all of NSF's programs help to develop and strengthen the nation's "intellectual capital." NSF's investments expand the reservoir of science and engineering knowledge, talent, and ideas, creating a valuable resource for our entire society. These investments contribute to the intellectual growth of talented scientists and engineers, and they provide opportunities for young people to work on projects at the cutting edge of science and engineering.

As is shown in Figure 5, the projects supported by NSF will involve an estimated 210,000 scientists, mathematicians, engineers, teachers, and students in FY 1996. This includes professional scientists and engineers engaged in research and teaching, recipients of NSF graduate and postdoctoral fellowships and traineeships, students at the graduate, undergraduate, and high school level participating in research projects, and other activities, such as secondary school students attending summer science camps.

Figure 5

**Numbers of People Involved in NSF Activities**

	FY 1995 Estimate	FY 1996 Estimate
Senior Researchers	25,300	26,100
Other Professionals	10,100	10,300
Postdoctoral Associates	4,400	4,500
Graduate Students	22,300	22,900
Undergraduate Students	22,400	22,800
K-12 Teachers	10,300	10,100
K-12 Students	105,100	113,700
Total Number of People	199,900	210,400

NSF also recognizes that to develop intellectual capital, it must draw upon a pool of ideas and talent that is as diverse and inclusive as possible. For this reason, NSF supports many programs -- including the Alliances for Minority Participation, the Visiting Professorships for Women, and Minority Postdoctoral Fellowships -- that aim to attract more women, minorities, and persons with disabilities to the science and engineering workforce. The Alliances for Minority Participation program (AMP), for example, has established the far-reaching goal of generating a nearly four-fold increase in the number of minority students receiving undergraduate degrees in science and engineering. The 20 AMP consortia, the oldest of which has been in operation for less than three years, have already produced a net increase of 1,500 baccalaureate science and engineering degrees awarded to students from underrepresented groups of the population.

*Strengthen the Physical Infrastructure.* Extending the frontiers of science and engineering requires advanced facilities, specialized equipment, highly-technical instruments, and effective logistical support. The infrastructure investments supported by NSF enable scientists and engineers to see farther into the universe and deeper into the structure of matter and living systems, while offering students and faculty the opportunity to work with cutting-edge technologies and conduct research in unique settings, such as the polar regions.

NSF's infrastructure investments comprise a balanced portfolio that includes large facilities such as astronomical observatories, particle accelerators, and research vessels as well as smaller, "table-top" instruments that are often developed and customized by scientists and engineers as part of their ongoing research. Key infrastructure investments in NSF's FY 1996 request include:

- Continuing Construction of LIGO -- The Laser Interferometer Gravitational Wave Observatory. When operational in 2001, LIGO will be the first large-scale facility capable of detecting gravitational waves. Gravitational waves were first predicted by Albert Einstein but have yet to be observed directly. NSF is seeking \$70 million for its Major Research Equipment Appropriation to fund continuing construction of LIGO.
- NSF support for instrumentation and other equipment used in research projects will increase by nearly 12 percent to a total of \$208 million. These investment generally yield

very high returns, as instruments developed to advance fundamental research are often adapted for uses in medicine, telecommunications, and other sectors.

- In Polar Programs, funding for arctic research will increase 23% to nearly \$32 million. As part of this increase, support for arctic logistics will triple, increasing by \$1.5 million over the 1995 level at which it was established. The logistics funds will provide coordinated support to the increasing number of large interdisciplinary projects located in the arctic region, including the design of an ice station camp in the Beaufort Sea.
- Support for Earth Science Facilities will increase by 15% to \$14 million. This includes support for the Global Seismic Network, which enables rapid analysis of earthquakes, monitoring of nuclear proliferation, and the study of thermal processes deep within the Earth.

Other infrastructure projects receiving increases in FY 1996 include the National High Magnetic Field Laboratory, the Cornell Electron Storage Ring, the National Radio Astronomy Observatory, the National Superconducting Cyclotron Laboratory, the National Center for Atmospheric Research, Supercomputer Centers, and the NSFNET. NSF's Academic Research Infrastructure program will be funded at \$100 million. Construction of the Gemini Telescopes will proceed with funds appropriated for FY 1995.

*Integrate Research and Education.* The best way to learn science is by doing science. Through learning experiences based on inquiry and discovery, students gain the ability to gather, analyze, and present complex information and to use advanced technologies in the workplace. For this reason, essentially everything NSF supports relates to learning at one level or another.

NSF's FY 1996 budget employs many different mechanisms that promote the close coupling of research and education in schools, colleges, and universities. Examples include:

- *Faculty Early Career Development Program (CAREER):* NSF established the CAREER program in FY 1995 to enable NSF-supported scientists and engineers to develop their skills in both research and teaching. The awards provide a framework for junior-level university faculty to link their research projects with their teaching and mentoring responsibilities. In FY 1996, NSF expects to provide approximately \$50 million for awards under the CAREER program.
- *Research Experiences for Undergraduates (REU):* NSF's REU programs nationwide that give undergraduate students the chance to participate directly in research projects. In FY 1996, NSF expects to increase its investment in REUs by 6% to a total of almost \$27 million.
- A number of programs within NSF's Education and Human Resources Account promote the effective use of technology and media for the teaching of math and science. For example, NSF supports such television programs as *Bill Nye the Science Guy* and *The Magic School Bus* and funds the development and distribution of teaching materials that complement the programming.



NSF also participates in the interagency Global Learning and Observations to Benefit the Environment (GLOBE) initiative.

*Promote Partnerships.* Partnerships are central to the Foundation's overall investment strategy. Reaching the agency's goals requires collaboration with many different partners, including the academic community, industry, elementary and secondary schools, other Federal agencies, state and local governments, international partners, and other institutions engaged in science and engineering. These partnerships improve the return on NSF's investments by forging stronger links between the agency's programs and their potential contribution to society.

NSF's proposed investments in FY 1996 will continue to foster innovative partnerships in research and education.

- NSF's Engineering, Mathematical and Physical Sciences, and Computer and Information Science and Engineering Activities support the Grant Opportunities for Academic Liaison with Industry (GOALI) program. GOALI allows scientists and engineers from university and industry to work together in a variety of settings and encourages collaboration at the conceptual stage of a research project. Total support for the GOALI program is expected to increase by at least \$5 million in FY 1996 to a total of approximately \$15 million.
- The NSF and the Environmental Protection Agency have entered an environmental research partnership. The partnership emphasizes the support and merit review of fundamental environmental research in three areas: 1) Water and Watersheds, 2) Technology for a Sustainable Environment, and 3) Valuation and Environmental Policy. NSF is devoting over \$8 million to this effort, and the combined investment by NSF and EPA exceeds \$20 million.
- The 18 NSF supported Long Term Ecological Research (LTER) sites have initiated an International Long Term Ecological Research Network that includes representatives from 17 nations. This activity will promote global scientific collaboration and data exchange in environmental research.

NSF's FY 1996 budget will also provide for sustained investments in other programs that foster partnerships, including Engineering Research Centers, Science and Technology Centers, and NSF's participation in government-wide initiatives coordinated by the National Science and Technology Council.

#### **Investments in Efficiency and Productivity**

Consistent with the Government Performance and Results Act (GPRA) and the National Performance Review (NPR), NSF is exploring and testing various mechanisms to streamline the agency's operations and improve its ability to serve the research and education community. These efforts are also intended to identify appropriate performance measures for NSF's programs in research and education.

- *FinanceNet:* NSF has worked closely with NPR staff to develop and coordinate FinanceNet -- a forum for exchanging ideas and promoting reinvention efforts in the financial management community.

- *FastLane*: FastLane is an experimental program relying on advanced information technologies, including the Internet and the World Wide Web, to redesign and streamline how NSF does business with the research and education community. Through FastLane, NSF forms are now available electronically via the Internet, and many financial transactions with the university community are conducted via electronic mail.

Also in accordance with the GPRA, NSF has established pilot projects to develop performance measures for its programs in research and education. These projects are currently reviewing the High Performance Computing and Communications Initiative, the Science and Technology Centers, and Specialized Research Facilities in the Mathematical and Physical Sciences. The results of these pilot projects will aid in implementing performance planning on an agency-wide basis.

## Conclusion

It was 50 years ago -- in July of 1945 -- that Vannevar Bush, science advisor to Presidents Roosevelt and Truman, issued his short but powerful treatise, *Science: The Endless Frontier*, which outlined the government's appropriate role in "promoting the flow of new scientific knowledge and the development of scientific talent in our youth." While our society has undergone many changes and endured nearly a half century of cold war since those words were written, the NSF continues to fulfill this role for our society, refining and updating Bush's original vision in keeping with the nation's evolving needs.

Today, America is moving forward into a new era. Science is now widely recognized not only as an endless frontier but also as an endless resource. In the November 1994 issue of the *Atlantic Monthly* magazine, the noted social scientist and corporate advisor Peter Drucker observed that our nation is entering a new economic order, "an economic order in which knowledge, not labor or raw material or capital, is the key resource." The ability of both nations and individuals to acquire and use knowledge, especially knowledge derived from science and technology, has become the primary determinant of our overall level of economic prosperity and social progress.

This presents a clear challenge to the National Science Foundation. Because the NSF's core purpose is to advance knowledge in science and engineering, it can and should provide the leadership necessary to help all Americans succeed in this new era and realize the benefits brought by scientific and technological progress. The research and education programs supported by NSF enable both the nation's capability to excel in science and engineering and the ability of individuals throughout our society to pursue opportunities in science and technology.

Through its strategic plan, the Foundation has developed an investment strategy in keeping with the growing importance of science and engineering as a national resource. NSF's FY 1996 budget request is built upon this strategy, and this investment will serve the national interest both today and well into the 21st Century.

## ACCOUNT SUMMARIES

Funding for the National Science Foundation is provided in the following seven appropriations.

### Research and Related Activities

The FY 1996 Budget Request for the Research and Related Activities (R&RA) Appropriation is \$2,454.00 million, an increase of \$174.00 million, or 7.6 percent, over the FY 1995 Current Plan of \$2,280.00 million. The R&RA Appropriation supports activities that enable the United States to uphold world leadership in all aspects of science and engineering, and to promote the discovery, integration, dissemination and employment of new knowledge in service to society. Research activities contribute to the achievement of these goals through expansion of the knowledge base, integration of research and education, stimulation of knowledge transfer among academia and the public and private sectors, and bringing the perspectives of many disciplines to bear on complex problems important to the nation.

Merit review is the principal tool in selecting among proposals for funding. Review emphasizes the capabilities of the investigators, the innovation, importance and relevance of the ideas and approaches, and the potential for enhancing the human and physical infrastructure of science and engineering.

A summary of the Activities within R&RA follows.

The **Biological Sciences (BIO)** Activity fosters understanding of the underlying principles and mechanisms governing life. Research ranges from the study of the structure and dynamics of biological molecules, such as proteins and nucleic acids, through cells, organs and organisms, to studies of populations and ecosystems. It encompasses processes that are internal to the organism as well as those that are external, and includes temporal frameworks ranging from measurements in real time through individual life spans, to the full scope of evolutionary time. The 7.6 percent increase, to a total of \$323.96 million in FY 1996, will primarily support research in biotechnology, biodiversity, and terrestrial ecology related to global change.

Research in the **Computer and Information Science and Engineering (CISE)** Activity includes system software design, theory of computing, engineering design, prototyping, testing, and deployment of cutting-edge computing and communications systems to address complex research problems. The 6.7 percent increase, to a total of \$275.57 million in FY 1996, is principally directed toward research in ubiquitous computing, human-machine interaction and information access, parallel and distributed computing, and toward multidisciplinary challenges -- laying the groundwork for future information technology that can help solve complex computational and communications intensive problems of scientific and societal importance. Additional experimental high-speed networking activities will be supported. The Supercomputer Centers will initiate new cooperative activities with other high performance computation facilities nationwide, and their computational infrastructure will be enhanced to carry out leading edge research.

The **Engineering (ENG)** Activity seeks to enhance long-term economic strength, security, and quality of life for the nation by fostering innovation, creativity, and excellence in engineering education and research. ENG seeks to promote the natural synergy between engineering education, fundamental research, and the application of technical knowledge. The ENG Activity's 7.7 percent increase, to a total of \$344.16 million for FY 1996, will primarily go to support research in areas such as intelligent sensing and control systems and environmentally conscious manufacturing. Funds are included to meet the mandated level for the Foundation-wide Small Business Innovation Research (SBIR) program and the authorized level for the Small Business Technology Transfer (STTR) program.

The **Geosciences (GEO)** Activity supports research in the atmospheric, earth, and ocean sciences. Basic research in the geosciences advances the scientific knowledge of the Earth's environment, including resources such as water, energy, minerals, biological diversity, and coral reefs. GEO supported research also advances the ability to predict natural phenomena of economic and human significance, such as climate changes, weather, earthquakes, fish-stock fluctuations, and disruptive events in the solar-terrestrial environment. The 7.6 percent increase, to \$451.48 million in FY 1996, will support fundamental research and national user facilities across the geosciences, including new and enhanced efforts in international programs, forecasting and climate modeling, and studies of continent-ocean margins.

The **Mathematical and Physical Sciences (MPS)** Activity supports research in mathematics, astronomy, physics, chemistry, and materials science. Major equipment and instrumentation such as particle accelerators and telescopes are provided to support the research needs of individual investigators. The 8.3 percent increase, to \$698.28 million in FY 1996, will be directed to areas including multidisciplinary research in optical science and engineering, environmental science and technology, biotechnology, nanosciences, and will enhance support for facilities and instrumentation.

The **Social, Behavioral and Economic Sciences (SBE)** Activity stimulates scientific progress in these fields. Research focuses on how various social and economic systems are organized and operate, and how cognitive and cultural factors influence human behavior. Activities include the Human Capital Initiative and a consortium for research on violence to be initiated in FY 1995. The Activity also includes programs that promote international scientific cooperation and provide authoritative data on science and engineering and the characteristics of the nation's research and education enterprise. The 8.0 percent increase, to \$122.87 million in FY 1996, will support research on human genetic diversity, learning and intelligent systems, and research on democratic processes.

Polar Programs, which includes the **U.S. Polar Research Programs** and **U.S. Antarctic Logistical Support Activities**, supports multi-disciplinary research in Arctic and Antarctic regions. Polar regions play a critical role in world weather and climate and provide unique research opportunities in environmental sciences, ranging from the ocean bottom, through the ice layer, and into space. The 6.1 percent increase in Polar Programs, to \$234.88 million, will be directed entirely to U.S. Polar Research Programs. Priority is given to increases for arctic research, including Arctic logistics. Increases are also provided for studies of the oceans surrounding Antarctica, research on Antarctic ice sheets, and for science facilities and operations that make Antarctic research possible.

The **Critical Technologies Institute** is a Federally-Funded Research and Development Center that provides analytical support to the Office of Science and Technology Policy by identifying near-term and long-term objectives for research and development, analyzing the production capability and economic viability of technologies; and providing options for achieving R&D objectives.

## **Education and Human Resources**

The FY 1996 Budget Request for Education and Human Resources (EHR) is \$599.00 million, a decrease of \$6.97 million, or 1.2 percent, from the FY 1995 Current Plan of \$605.97 million. EHR supports a cohesive and comprehensive set of activities, augmented by informal science experiences, which encompass every level of education and every region of the country. EHR is a major participant in interagency efforts for science, mathematics, engineering and technology education (SMETE) initiative, totaling \$530.88 million in FY 1996. This initiative addresses many of the challenges posed by *Goals 2000: Educate America Act*.

- Support at the K-12 level totals \$354.78 million, a decrease of \$810,000 from the FY 1995 Current Plan. This support is focused primarily in the Systemic Reform activities (\$95.35 million) in states,

urban, and rural areas, and Elementary, Secondary and Informal Science activities that enable all students to achieve in science, mathematics, engineering and technology education

- Support at the **Undergraduate** level is \$102.50 million, a decrease of \$640,000 from the FY 1995 Current Plan. This support is focused primarily on improving undergraduate preparation of K-12 teachers and addressing advanced technician training. Efforts of reforming curriculum and laboratory instruction, and upgrading equipment continue to be major emphases.
- Support at the **Graduate** level is \$67.50 million, unchanged from the FY 1995 level. This support maintains the modest increases in both the stipend and the cost of education allowance provided in FY 1995 for the Graduate Fellowship program. The number of fellows will remain at approximately 2,400. The Graduate Research Traineeship program will be sustained at the FY 1995 level to maintain support for ongoing projects. No new traineeship positions are planned.
- **Advanced Technological Education (ATE)** established in FY 1994, is \$23.35 million, unchanged from the FY 1995 level. Support will continue to focus on improving curriculum development and program improvement at the secondary and undergraduate levels to help transition students to the increasingly technology-based workforce.

### Academic Research Infrastructure

The FY 1996 Budget Request for the Academic Research Infrastructure (ARI) Activity is \$100 million, a decrease of \$18.13 million, or 15.3 percent, from the FY 1995 Current Plan of 118.13 million.

The FY 1995 Appropriation originally included \$118.13 million for NSF's Academic Research Infrastructure Activity, and an additional \$131.87 million for an interagency infrastructure program, for a total appropriation of \$250 million. The availability of funds for an interagency program is contingent on the development of an interagency program for FY 1996. The Administration has elected not to initiate such a program and has proposed rescission of the \$131.87 million, resulting in an FY 1995 Current Plan of \$118.13 million.

In FY 1996, NSF is requesting \$100 million for Academic Research Infrastructure, which will be equally divided between facilities and instrumentation. This represents an increase of 81.8 percent over the FY 1995 Request of \$55 million. NSF believes that \$100 million will provide for continued progress on renewal of these important research resources while maintaining an appropriate balance between support for research activities and infrastructure.

### Major Research Equipment

The FY 1996 Request for the Major Research Equipment (MRE) appropriation is \$70 million. MRE was established in FY 1995 to support construction of major research facilities that provide unique capabilities at the cutting edge of science and engineering. The FY 1996 request of \$70 million represents a \$56 million decrease, or -44.4 percent, below the FY 1995 level for these items.

Projects supported by this Account will push the boundaries of technology and will offer significant expansion of opportunities, frequently in totally new directions, for the science and engineering community. Two projects currently comprise the Major Research Equipment Account: the Laser Interferometer Gravitational Wave Observatory (LIGO) and the Gemini telescopes, twin eight-meter telescopes in the northern and southern hemispheres, being built through an international partnership.

Per Congressional action, \$35 million made available for LIGO in FY 1994 within the Research and Related Activities account was rescinded. This \$35 million was restored for LIGO in the FY 1995 MRE account, with an additional \$50 million requested. This brings the FY 1995 total funding for LIGO to \$85 million. Also, in addition to the FY 1995 request of \$20 million for the Gemini telescopes, Congress appropriated another \$21 million, for a total of \$41 million in FY 1995. Funding for construction of the Gemini telescopes was completed in FY 1995. No additional funds will be requested for construction of the Gemini telescopes in FY 1996.

The \$70 million request in FY 1996 will permit the LIGO project to progress toward completion of construction in FY 1998 and a transition to operations during FY 1999.

### **Salaries and Expenses**

The FY 1996 Request for Salaries and Expenses (S&E) is \$127.31 million, an increase of \$3.34 million, or 2.7 percent, over the FY 1995 Current Plan level of \$123.97 million. The Request level supports an authorized ceiling of 1,226 full-time equivalents (FTEs), provides for current administrative levels, and continues the investment in information technology for administrative processes.

Salaries and Expenses provides funds for staff salaries and benefits, and general operating expenses necessary to manage and administer the NSF. Funds are requested separately for FTEs and direct expenses of the Office of Inspector General and for NSF Headquarters Relocation, the appropriation account which includes funds to reimburse the General Services Administration (GSA) for expenses incurred to relocate the Foundation to its new Headquarters location in Arlington, Virginia.

### **NSF Headquarters Relocation**

The FY 1996 Request for NSF Headquarters Relocation is \$5.20 million, equal to the FY 1995 level. This appropriation account provides annual reimbursement to the General Services Administration (GSA) through FY 1999 for expenses incurred by GSA pursuant to the relocation of the National Science Headquarters to Arlington, Virginia, which was completed in January 1994.

### **Office of Inspector General**

The Office of Inspector General (OIG) was established to promote economy, efficiency, and effectiveness in administering the Foundation's programs, to detect and prevent fraud, waste, or abuse within NSF or by individuals that request or receive NSF funding, and to identify and resolve cases of misconduct in science. The FY 1996 Request for the OIG is \$4.49 million, an increase of \$0.11 million over the FY 1995 Current Plan.

## MODES OF SUPPORT

The National Science Foundation funds a broad range of activities focused on strengthening the nation's scientific and engineering research enterprise. Support for research and education activities comes in many forms. Research project awards are made to individuals and small groups of investigators and include support for postdoctoral researchers and students. NSF also supports research centers, national user facilities, development and acquisition of instrumentation for individual or shared use, graduate and postdoctoral fellowships, systemic educational reform activities, and workshops and conferences. These activities can be characterized as follows:

(Millions of Dollars)				
Modes of Support	FY 1994 Estimate	FY 1995 Estimate	FY 1996 Estimate	% Change FY 1995 -1996
Research Projects	\$1,485	\$1,560	\$1,672	7.2%
Facilities	604	738	710	(3.7%)
Centers	186	202	208	3.0%
Education & Training	585	630	633	0.4%
<b>TOTAL <sup>1</sup></b>	<b>\$2,860</b>	<b>\$3,131</b>	<b>\$3,223</b>	<b>3.0%</b>

<sup>1</sup> Excludes Salaries and Expenses, NSF Headquarters Relocation, and Office of Inspector General

### Research Projects

Research projects provide support for individuals and small groups devoted both to disciplinary research in traditional fields and to cross-disciplinary fields of national importance. Components of projects include support for researchers along with postdoctoral associates and undergraduate or graduate assistants. Funding is also provided for the instrumentation and equipment necessary to perform research, as well as other related costs such as travel and conference support. In addition, some funding may be included for items such as data bases, laboratories, and museums. Also included under this mode is support targeted for young investigators, women and minority researchers, as well as funding to meet the Foundation's statutory requirements for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

### Facilities

NSF supports large, multi-user facilities which require long-term commitments of support. These facilities are characteristically too large, complicated, or expensive for individual researchers or small distributed groups to construct alone. Support for these national facilities is essential to advance U.S. research capabilities to perform world class research. These facilities meet the need for multi-user access to state-of-the-art research facilities that would otherwise be unavailable. Facility support includes funds to build, maintain, renovate, or operate NSF user facilities.

NSF facilities include the National Center for Atmospheric Research, Gemini 8-meter telescopes, the National High Magnetic Field Laboratory, the Laser Interferometer Gravitational Wave Observatory, national astronomy centers, NSFNET, the oceanographic research fleet, the nanofabrication facility, and supercomputing centers. Support is also provided for research and research training facilities modernization, and for arctic and antarctic logistics needs.

## Centers

NSF support for centers is based on the premise that some scientific questions and research problems can best be addressed through the multidisciplinary, long-term, coordinated efforts of many researchers. Although the individual centers' goals are diverse, NSF's centers share common traits, including well-defined coordination with industry to ensure the timely transfer of knowledge into the private sector. Centers also have strong educational components, aiding in the training of the nation's next generation of scientists and engineers and encouraging students of all ages to participate in science.

Types of centers supported by NSF include Science and Technology Centers, Engineering Research Centers, the National Center for Earthquake Engineering Research, the Center for Ecological Analysis and Synthesis, Long Term Ecological Research Sites, Materials Research Science and Engineering Centers, Minority Research Centers of Excellence, Industry/University Cooperative Research Centers, State Industry/University Cooperative Research Centers, and the National High Field FT-ICR Mass Spectrometry Center.

## Education & Training

NSF's education and training programs support activities from kindergarten through postdoctoral levels, and also include public science literacy. NSF efforts in education and training programs are aimed at enabling U.S. students to become scientifically literate citizens as well as ensuring a well-trained workforce that can maintain U.S. leadership in science and technology.

Programs for K-12 education and training include rural, urban, and statewide systemic reform initiatives, teacher enhancement programs, and teacher preparation programs. At the undergraduate level, NSF supports course and curriculum development, Engineering Education Coalitions, and the Advanced Technological Education program. Graduate programs include research fellowships, research traineeships, and research training groups, as well as dissertation improvement awards.

In some shape or form, virtually all NSF programs actually have an education and training component, through developing knowledge and skills which participants did not have before. Additional support for educational and training efforts provided through research projects, centers and facilities also includes targeted funds for activities such as Research Experiences for Undergraduates and Research in Undergraduate Institutions. Research grants also provide support targeted for investigators early in their careers such as Presidential Faculty Fellows and the Faculty Early Career Development Program (CAREER).

Through all of these modes of support, NSF also places special emphasis on groups which have been historically underrepresented in science and engineering fields, namely, women, minorities, and persons with disabilities. Programs supporting historically underrepresented groups include: Research Improvement in Minority Institutions, Visiting Professorships for Women, Minority Research Centers of Excellence, and Model Institutions for Excellence.



## CENTERS

The National Science Foundation supports a variety of centers programs. While the programs are diverse, they do share several premises:

- Some scientific questions and research and technical problems can best be addressed through the multidisciplinary, long-term, coordinated research efforts of a number of scientists and engineers working together on fundamental research addressing the many facets of a complex problem;
- A strong educational component to aid the training of this nation's next generation of scientists and engineers and to encourage the participation in science and engineering of students of all ages; and
- A well-defined coordination with industry to ensure that research is relevant to national needs and that knowledge quickly migrates into the private sector

NSF plans to support 170 centers by the close of FY 1995. In FY 1996, no new center programs will be initiated; however, there will be competitions within some of the existing center programs possibly leading to some turnover within the programs. The centers and center programs are listed below.

(Millions of Dollars)

	Year of Program Initiation	FY 1995 Number of Centers	FY 1995 Estimate	FY 1996 Estimate	Percent Change
Engineering Research Centers	1985	21	\$51.73	\$52.43	1.4%
Science & Technology Centers	1987	25	60.47	62.01	2.5%
Industry/University Cooperative Research Centers	1973	53	4.13	4.13	0.0%
State Industry/University Cooperative Research Centers	1991	10	3.72	4.02	8.1%
Minority Research Centers of Excellence	1987	8	7.98	7.73	-3.1%
Materials Research Science & Engineering Centers	1972	29	44.41	47.41	6.8%
Center for Ecological Analysis and Synthesis	1995	1	2.00	2.00	0.0%
Long-Term Ecological Research Sites	1980	18	12.20	12.20	0.0%
National Center for Earthquake Engineering Research	1988	1	4.00	4.00	0.0%
National Center for Environmental Decision-Making Research	1995	1	1.00	1.00	0.0%
Research Centers on the Human Dimensions of Global Change	1995	NA	5.00	5.00	0.0%
National Consortium for Research on Violence	1995	1	2.00	2.00	0.0%
National High Field FT-ICR Mass Spectrometry Center	1994	1	1.00	1.00	0.0%
Critical Technologies Institute	1993	1	2.00	2.80	40.0%
<b>TOTAL</b>		<b>170</b>	<b>\$201.64</b>	<b>\$207.73</b>	<b>3.0%</b>

## Engineering Research Centers

The Engineering Research Center (ERC) program was established to address fundamental research issues crucial to the next generation of technological advances from an engineering systems perspective, and to educate a new generation of engineering students using a cross-disciplinary team approach to problem solving. All ERCs focus on research critical to U.S.

economic competitiveness, and have a strong education outreach component. They also give priority to the timely transfer of technological advances to industry and other users.

NSF's annual funding of each ERC averages approximately \$2.5 million, with a range of \$1.3 million to \$3.0 million. Total funding from all sources, including industry, averages about 2.5 times the NSF contribution. In 1994, the 18 ongoing ERCs had active partnerships with over 416 firms and industrial consortia; these partnerships involved almost 400 joint projects. Over the ten year life of the program, the ERCs produced 216 patents and 1161 licenses for software and other developments.

### **Science and Technology Centers**

The Science and Technology Centers (STCs) Program supports innovative interdisciplinary research, education, and knowledge transfer efforts in fields of basic science and mathematics. STCs are fostering new approaches that signal a new collaborative culture among university- and industry-based researchers and educators at all levels, from kindergarten to graduate school. The Centers provide opportunities to explore research problems that require interdisciplinary expertise, access to state-of-the-art instrumentation and facilities, and a commitment of high levels of support for sustained periods of time. NSF's annual funding for each STC averages approximately \$2.4 million per year. Additional funding from other sources including 275 industrial partners totaled over \$51 million in FY 1994.

STCs have an impressive record of research accomplishments, research training, contributions to K-12 education, and timely transfer of knowledge and technology from the laboratory to industry. Traditional barriers among disciplines and between university, governmental, and industry laboratories have been reduced, creating a new mode of leadership and management in research and education. STC research has supported the training of hundreds of graduate students and postdoctoral fellows, has pursued research of interest to industrial advisors, has engaged scores of industrial researchers in basic research, and has spawned new companies, products, and jobs. STC research has contributed new liquid crystalline technologies that are being incorporated into commercial liquid crystal displays; new tools and algorithms that enable scientists and engineers to utilize parallel computation more effectively, new knowledge that is being used to identify and prepare new material systems for application in civilian and military aircraft, electronics packaging, dental and medical devices, structural adhesives and civil infrastructure; new technologies for bioremediation; and a variety of other developments serving the national interest. The STCs have submitted 71 patent applications and been granted 42 patents.

### **Industry/University Cooperative Research Centers & State Industry/University Cooperative Research Centers**

The Industry/University Cooperative Research Centers (I/UCRCs) encourage industrial investment in academic research by developing partnerships to support industrially relevant research. NSF currently supports over 50 centers involving about 1,800 faculty and students who work with 600 firms across the nation. The research results of these centers have spawned a wide range of changes in industrial processes and numerous advances that have resulted in commercially viable products and technologies.

The State Industry/University Cooperative Research Centers seek to build on industrially relevant research in order to enhance local and regional economic development, and actively focus on technology transfer. The support of these research centers is shared by NSF, state governments, and industry. Currently, NSF supports ten centers, in which 168 companies are working with over 600 faculty and students. NSF's average annual support of \$300,000 to each center is matched by state support and augmented by over three times that amount from industrial contributions.

### **Minority Research Centers of Excellence**

The goals of the Minority Research Centers of Excellence (MRCE) program are to upgrade and expand the research capabilities of the most productive minority institutions and to increase the number of baccalaureate and doctorate degrees earned by minority students as well as to address research questions requiring a multidisciplinary center-based approach. Institutions with MRCE grants serve as regional research and training centers through interactions and collaborations with other institutions, other NSF and Federal programs, and with the industrial sector.

### **Materials Research Science and Engineering Centers**

The Materials Research Science and Engineering (MRSEC) program supports interdisciplinary materials research addressing fundamental problems of intellectual and strategic importance. The centers have strong links to industry and other sectors, and support educational outreach to other institutions. The MRSEC Program supersedes the Materials Research Laboratories (MRL) and Groups (MRG) programs. There are currently 29 centers, laboratories, or groups within the program.

The MRSECs include broad based centers with diverse research agendas as well as those which are scientifically more focused. The broader centers, including the former MRLs, feature research at the cutting edge of materials science and engineering in areas such as polymers and biomolecular materials, electronic and photonic nanostructures, superconducting and superhard materials, oxide surfaces and magnetic systems, as well as a design and manufacturing initiative. The more focused centers, including the former MRGs, emphasize specific areas of scientific and strategic importance such as magnetic materials for information storage, sensors for automobile control and diagnostics, and the development of enabling technologies for manufacture of electronic materials.

### **Center For Ecological Analysis and Synthesis**

In FY 1995, NSF is initiating support for a Center for Ecological Analysis and Synthesis (CEAS). This center, coordinated with the Long Term Ecological Research Sites, will promote integrative studies of complex ecological questions and serves as a locus for the synthesis of large data sets. The goals of the Center are to advance the state of ecological knowledge through the search for universal patterns and principles and to organize and synthesize ecological information so that it will be useful to researchers, policy makers and resource managers addressing important environmental issues.

### **Long Term Ecological Research Sites**

The Long Term Ecological Research Site (LTER) program supports long-term analysis of ecological phenomena, both natural and human influenced, comparisons of observations across diverse ecosystems, integration of information from multiple sites and multidisciplinary projects through cross-site syntheses, and provision of large, secure, ecologically diverse sites with well-developed support capabilities. Extensive computer modeling allows regional, national and international synthesis efforts.

LTER research is documenting the impact of human versus natural disturbances on ecosystem structure and function. In a series of experiments, LTER researchers determined that major storms change forest structure but have little long-term impact on forest processes such as decomposition and mineral cycling. In contrast, research in which the soil was artificially warmed a few degrees led to little change in forest structure but major changes in ecosystem processes.

Since long-term forest productivity depends on sustaining important ecosystem processes, this information is vital to natural resource planning.

#### **National Center for Earthquake Engineering Research**

The National Center for Earthquake Engineering Research furthers earthquake hazard mitigation through an integrated research and technology transfer program that focuses on the structural and non-structural components of buildings, lifelines (such as power and communications networks), roads, and bridges. It has launched a major new research initiative on civil infrastructure systems to develop guidelines for designing earthquake-resistant highways and bridges and for retrofiting existing systems. Additional funding for the center is provided by other federal agencies and the state of New York.

#### **National Center for Environmental Decision-Making Research**

In FY 1995, NSF will establish a National Center for Environmental Decision-Making Research. The goal of the center is to improve the scientific basis for government and industrial decision making on the environment by synthesizing research results from a variety of sources.

#### **Research Centers on the Human Dimensions of Global Change**

In FY 1995, NSF will establish a consortium of Research Centers and Research Teams on the Human Dimensions of Global Change. The goals of these centers and teams are to facilitate the progress of Human Dimensions of Global Change (HDGC) research; promote the education and training of researchers ranging from undergraduate to post-doctoral levels; and foster interdisciplinary and multidisciplinary research collaborations on HDGC issues. In order to capitalize on the synergies inherent in collaborative efforts, all supported institutions will be networked into a consortium of research teams and research centers.

#### **National Consortium for Research on Violence**

In FY 1995, NSF will establish a National Consortium for Research on Violence. Because violence involves multi-level phenomena, there is a particular need for interdisciplinary collaboration in order to integrate scientific knowledge across multiple levels of analysis. To that end, the consortium will consist of a collaboration of researchers from different disciplines and different universities, research centers, or other institutions. The consortium will embody a program of fundamental research focused on the development of integrated theories, the facilitation of collaborative methodological research, and the promotion of intellectual exchange and research that cuts across disciplines. Effective mechanisms to disseminate information about findings and data to those in a position to apply the knowledge will be included. An important component of the consortium will be the training of the next generation of researchers in interdisciplinary approaches to understanding violence and to increase the participation of underrepresented groups in research on violence.

#### **National High Field FT-ICR Mass Spectrometry Center**

In FY 1994 the National High Field FT-ICR Mass Spectrometry Center was established as an adjunct to the National High Field Magnet Laboratory (NHFML). The Center will take advantage of advances in magnet technology to develop mass spectrometers of unprecedented mass range and resolution. The new instruments developed at the Center will enable research across a wide range of scientific disciplines, allowing, for example, the direct sequencing of large proteins so that they may be produced in quantities needed for bioprocessing, or the routine analysis of complex chemical mixtures needed to identify trace contaminants in crude oil.

### Critical Technologies Institute

The Critical Technologies Institute is a Federally-Funded Research and Development Center that provides analytical support to the Executive Branch, policy guidance for the Institute is provided by an external Operating Committee, which functions as the governing board of the Institute. The views of U.S. industry, colleges and universities, and Federal and State agencies involved in research and development or utilization of technologies considered critical for U.S. global economic or defense leadership, are analyzed. Through such analyses, the Institute identifies near-term and long-term objectives for research and development, analyzes the production capability and economic viability with respect to such technologies, and provides options for achieving those objectives.

### 1994 Estimates

(Millions of Dollars)

	Number of Participating Institutions	Number of Partners	Total NSF Support	Total Leveraged Support	Number of Participants
Engineering Research Centers	18	416	\$51.25	\$96.40	3,370
Science & Technology Centers	83	330	57.62	51.18	3,710
State & Industry/University Cooperative Research Centers	89	768	7.43	60.50	2,430
Minority Research Centers of Excellence	8	68	8.82	6.67	3,373
Materials Research Science and Engineering Centers	34	190	41.90	75.00	2,630
National Center for Earthquake Engineering Research	23	16	4.00	5.70	90
Long Term Ecological Research Sites	187	34	12.20	2.60	1,610
National High Field FT-ICR Mass Spectrometry Center	9	1	1.40	0.59	30
Critical Technologies Institute	NA	NA	1.50	NA	NA
<b>TOTAL</b>	<b>451</b>	<b>1823</b>	<b>\$186.12</b>	<b>\$298.64</b>	<b>17,243</b>

**Total Number of Participating Institutions:** all academic institutions which participate in activities at the centers

**Number of Partners:** the total number of non-academic participants, including industry, states, and other federal agencies, at the centers

**Leveraged Support:** funding for centers from sources other than NSF.

**Number of Participants:** the total number of people who utilize center facilities, not just persons directly supported by NSF

## Centers Supported by the National Science Foundation

	Institution	State
<b>Engineering Research Centers</b>		
Neuromorphic Systems Engineering	California Inst of Tech	CA
Particle Science & Technology	U of Florida	FL
Low Cost Electronic Packaging	Georgia Inst of Tech	GA
Optoelectronic Computing Systems	U of Colorado	CO
Compound Semiconductor Microelectronics	U of Illinois	IL
Collaborative Manufacturing	Purdue U	IN
Biotechnology Process Engineering	Massachusetts Inst. Tech	MA
Systems Research Center	U of Maryland	MD
Interfacial Engineering	U of Minnesota	MN
Computational Field Simulation	Mississippi State U	MS
Biofilm Engineering	Montana State U	MT
Advanced Electronic Materials Processing	North Carolina State U	NC
Emerging Cardiovascular Technologies	Duke U	NC
Telecommunications Research	Columbia U	NY
Net Shape Manufacturing	Ohio State U	OH
Advanced Technology for Large Structural Systems	Lehigh U	PA
Engineering Design	Carnegie Mellon U	PA
Data Storage Systems	Carnegie Mellon U	PA
Offshore Technology	Texas A&M	TX
Advanced Combustion Engineering	Brigham Young U	UT
Plasma-Aided Manufacturing	U of Wisconsin	WI
<b>Science and Technology Centers</b>		
Center for Advanced Cement-Based Materials	Northwestern U	IL
Ultrafast Optical Science	U of Michigan	MI
Advance Liquid Crystalline Optical Materials	Kent State U	OH
Particle Astrophysics	U of California	CA
Molecular Biotechnology	U of Washington	WA
Quantized Electronic Structures	U of California	CA
Astrophysical Research in Antarctica	U of Chicago	IL
Photoinduced Charge Transfer	U of Rochester	NY
Magnetic Resonance Technology for Basic Biological Research	U of Illinois	IL
Computer Graphics and Scientific Visualization	U of Utah	UT
Analysis and Prediction of Storms	U of Oklahoma	OK
Biological Timing	U of Virginia	VA
Center for Research on Parallel Computing	Rice U	TX
Light Microscope Imaging and Biotechnology	Carnegie Mellon U	PA
Clouds, Chemistry, and Climate	U of Chicago	IL
Synthesis, Growth, and Analysis of Electronic Materials	U of Texas	TX
Southern California Earthquake Center	U of Southern California	CA
Computation and Visualization of Geometric Structures	U of Minnesota	MN
Research in Cognitive Science	U of Pennsylvania	PA
Engineering Plants for Resistance Against Pathogens	U of California	CA
Superconductivity	U of Illinois	IL
Discrete Mathematics and Theoretical Computer Science	Rutgers U	NJ
Microbial Ecology	Michigan State U	MI
High Pressure Research	State U of New York	NY
High Performance Polymetric Adhesives and Composites	VA Polytechnic Institute	VA
<b>Industry/University Cooperative Research Centers</b>		
Nondestructive Evaluation	Iowa State U	IA
Dimensional Measurement and Control in Manufacturing	U of Michigan	MI
U of MA Industry Research on Polymers	U of Massachusetts	MA
Ceramic Research	Rutgers	NJ
Microcontamination Control	U of Arizona	AZ
Electromagnetics Research	Northeastern U	MA
Engineering Tribology	Northwestern U	IL

## Glass Research

Center for Microengineered Ceramics  
 Nanostructural Materials Research  
 Process Analytical Chemistry  
 Measurement and Control Engineering Center  
 Building Performance and Diagnostics  
 Advanced Electron Devices and Systems  
 Ultra-High Speed Integrated Circuits and Systems  
 IUCRC for Biosurfaces  
 Information Management Research  
 Wireless Information Networks  
 Hazardous Substance Management  
 Air Conditioning and Refrigeration Center  
 Simulation and Design Optimization of Mechanical Systems  
 Aseptic Processing and Packaging Studies  
 Material Handling Research Center  
 Web Handling Research Center  
 Grinding Research & Development  
 Berkeley Sensor & Actuator Center  
 Applied Polymer Research  
 Dielectric Studies  
 Advanced Steel Processing and Products Research Center  
 Iron and Steelmaking Research  
 Research Center for Energetic Materials  
 Cooperative Research Center in Coatings  
 Polymer Interfaces Center  
 Chemical Process Modeling and Control  
 Separations Using Thin Films  
 Optical Circuitry Cooperative  
 Microwave/Millimeter-wave Computer-aided Design  
 Design of Analog-Digital Integrated Circuits  
 Software Engineering Research Center  
 Center for Communications and Signal Processing  
 Machine Tools Systems  
 Corrosion  
 Ocean Technology  
 Composite Design & Manufacturing  
 Emission Reduction  
 Biodegradation  
 High-Speed Image/Signal Processing  
 Advanced Communications  
 Innovation Management Studies  
 Health Management Research  
 Integrated Pest Management

**State Industry/University Cooperative Research Centers**

Microstructure Composites  
 Electronic Packaging  
 Intelligent Information Retrieval  
 Polymer Composite Processing  
 Capsule Pipeline for Coal  
 Nonwoven Textiles  
 Rock Mechanics  
 Electronic Imaging  
 Electronic Packaging  
 Biomaterials

**Minority Research Centers of Excellence**

Analysis of Structures and Interfaces  
 Cellular and Molecular Biology

NY State College of Ceramics NY  
 U of New Mexico NM  
 U of North Texas TX  
 U of Washington WA  
 U of Tennessee TN  
 Carnegie Mellon U PA  
 U of Texas TX  
 U of California CA  
 State U of New York NY  
 U of Arizona AZ  
 Rutgers NJ  
 New Jersey Inst of Tech NJ  
 U of Illinois IL  
 U of Iowa IA  
 North Carolina State U NC  
 GA Institute of Technology GA  
 Oklahoma State U OK  
 U of Connecticut CT  
 U of California CA  
 Case Western Reserve U OH  
 Pennsylvania State U PA  
 Colorado School of Mines CO  
 Carnegie Mellon U PA  
 NM Inst of Mining & Tech. NM  
 Eastern Michigan U MI  
 Lehigh U PA  
 Lehigh U PA  
 U of Colorado CO  
 U of Arizona AZ  
 U of Colorado CO  
 Washington State U WA  
 Purdue U IN  
 North Carolina State U NC  
 U of Illinois IL  
 Ohio U OH  
 U of Rhode Island RI  
 Stanford U CA  
 NJIT NJ  
 U of Massachusetts MA  
 U of California CA  
 Villanova U PA  
 Lehigh PA  
 Arizona State U AZ  
 North Carolina State U NC  
 Case Western Reserve U OH  
 U of Maryland MD  
 U of Massachusetts MA  
 Michigan State U MI  
 U of Missouri MO  
 North Carolina State U NC  
 U of Oklahoma OK  
 U of Rochester NY  
 State U of New York NY  
 U of Texas TX  
 City College of New York NY  
 Meharry Medical College TN

Materials Science	U of Texas at El Paso	TX
Nuclear/High Energy Physics	Hampton U	VA
Nonlinear Optics and Optical Materials	Alabama A&M U	AL
Materials Science	Howard U	Wash D C
Tropical and Caribbean Research	U of Puerto Rico	PR
Theoretical Studies of Physical Systems	Clark Atlanta U	GA
<b>Materials Research Science and Engineering Centers</b>		
High Pressure Synthesis of Materials	Arizona State U	AZ
Micro-mechanics of Failure-Resistant Materials	Brown U	RI
Ultrafast Spectroscopy of Nanostructures	Brown U	RI
Hysteresis and Transport in Magnetic Particles and Thin Films	U California San Diego	CA
Metastable Growth of Diamond and Diamond-Like Materials	Case Western Reserve U	OH
Structure, Dynamics, and Transitions in Polymer Liquid Crystals	Case Western Reserve U	OH
Ferroelectric Liquid Crystals	U of Colorado Boulder	CO
Environmental and Stochastic Aspects of Creep Crack Growth	Lehigh U	PA
Adsorption, Epitaxy, and Growth: The Role of Steps	U of Maryland	MD
Studies in Physical Adsorption	Pennsylvania State U	PA
Size Effects in Ferric Solids	Pennsylvania State U	PA
Princeton University	Princeton U	NJ
Dilute Magnetic Semiconductors and their Superlattices	Purdue U	IN
Grain Boundaries of High Temperature Superconductors	U of Wisconsin	WI
Mechanisms of Film Growth Using Chemical Vapor Deposition	U of Wisconsin	WI
University of Chicago	U of Chicago	IL
Harvard University	Harvard U	MA
Massachusetts Institute of Technology	Mass Inst of Tech	MA
Center for the Science of New Materials	Northwestern U	IL
Stanford University	Stanford U	CA
Cornell University	Cornell U	NY
University of Illinois, Urbana/Champaign	U of Illinois	IL
University of Massachusetts, Amherst	U of Massachusetts	MA
University of Pennsylvania	U of Pennsylvania	PA
Magnetic Materials for Information Technology	U of Alabama	AL
Sensor Materials for Automotive Control and Diagnostics	Michigan State U	MI
Technology-Enabling Heterostructure Materials	Purdue U	IN
Center for Polymer Interfaces and Macromolecular Assemblies	Stanford U	CA
University of California, Santa Barbara	U of California	CA
<b>National Center for Earthquake Engineering Research</b>		
<b>Long Term Ecological Research Sites</b>		
Arctic Tundra	Marine Biological Lab	MA
Cedar Creek Natural History Area	U of Minnesota	MN
Coweeta Hydrologic Laboratory	U of Georgia	GA
Hubbard Brook Experimental Forest	Syracuse U	NY
Kellogg Biological Station	Michigan State U	MI
Luquillo Experimental Forest	Inst. of Tropical Forestry	PR
Niwot Ridge-Green Lakes Valley	U of Colorado	CO
Palmer Station, Antarctica	U of California	CA
Virginia Coast Reserve	U of Virginia	VA
H J Andrews Experimental Forest	Oregon State U	OR
Bonanza Creek Experimental Forest	U of Alaska	AK
Central Plains Experimental Range	Colorado State U	CO
Harvard Forest	Harvard U	MA
Jornada Experimental Range	Duke U	NC
Konza prairie Research Natural Area	Kansas State U	KA
McMurdo Dry Valleys	Desert Research Institute	NV
North Temperate Lakes	U of Wisconsin	WI
Seville National Wildlife Refuge	U of New Mexico	NM
<b>National High Field FT-ICR Mass Spectrometry Center</b>		
<b>Critical Technologies Institute</b>		
	Florida State U	FL
	RAND Corporation	CA



## FACILITIES

The National Science Foundation supports large, multi-user facilities which require long-term commitments for support. These facilities are usually of a scale too large, complex, or expensive for individual or small groups of researchers to construct. They meet the need for multi-user access to state-of-the-art research facilities that would otherwise be unavailable. Support for these unique National facilities is essential to advance U.S. research capabilities required for world-class research. Support also includes funding for staff and support personnel to assist scientists in conducting research at the facilities.

NSF supports the following facilities:

(Millions of Dollars)				
	FY 1994 Estimate	FY 1995 Estimate	FY 1996 Estimate	% Change 95 - 96
Advanced Scientific Computing Centers	66.90	70.90	74.90	5.6%
NSFNET	39.11	45.22	46.22	2.2%
National Center for Atmospheric Research	53.30	59.18	65.63	10.9%
National Astronomy Centers	65.45	63.38	70.39	11.1%
Laser Interferometer Gravitational Wave Observatory	0.03	85.00	70.00	-17.6%
National High Magnetic Field Laboratory	12.00	12.00	15.00	25.0%
GEMINI 8-Meter Telescopes	17.01	41.00	0.00	-100.0%
National Nanofabrication Users Network	3.45	3.55	3.80	7.0%
Academic Research Fleet/Ship Operations	49.06	49.20	53.00	7.7%
Academic Research Infrastructure	53.04	59.07	50.00	-15.4%
Polar Facilities	168.64	166.77	171.77	3.0%
Other Facilities <sup>1</sup>	75.56	82.49	89.49	8.5%
<b>TOTAL</b>	<b>\$603.55</b>	<b>\$737.76</b>	<b>\$710.20</b>	<b>-3.7%</b>

<sup>1</sup>Other facilities include physics, materials research, ocean sciences, atmospheric sciences, and earth sciences facilities.

### Advanced Scientific Computing Centers

These facilities provide scientists and engineers access to advanced state-of-the-art high performance computers at four national Supercomputer Centers: San Diego Supercomputer Center, National Center for Supercomputing Applications (University of Illinois), Pittsburgh Supercomputer Center, and Cornell National Supercomputer Facility. The supercomputing centers are dedicated to serving long-term needs, including training for the use of advanced computing by the academic research community. They are also continually updated. Approximately 60% of the funding for these centers is provided by NSF, with the remainder of the funding coming from industry, states, universities and other federal agencies.

### NSFNET

The NSFNET enables and expands scholarly communication and collaboration by providing network access for researchers and educators to high performance, remote scientific facilities (including supercomputer centers), and to information resources. This includes support for interconnection of mid-level networks, supercomputer centers, and other federal agency networks. Network connections to mid-level networks from institutions of higher learning, pre-college institutions, and libraries are also supported. With joint funding from other nations, links between NSFNET and research and education networks around the world are supported.

Funding is also provided for promising developmental and demonstration networking projects deriving from networking and communications research

#### **National Center for Atmospheric Research (NCAR)**

NCAR facilities serve the entire atmospheric sciences research community and part of the ocean sciences community. Facilities available to university, NCAR, and other researchers include a computing center providing advanced computational resources and services emphasizing the development and execution of large models and for the archiving and manipulation of large data sets. NCAR provides research aircraft which can be equipped with sensors to measure meteorological and chemical state parameters, including temperature, pressure, dew point, winds, and ozone. NCAR plans include enhancing the current computer capabilities to support large, long-running simulations of Earth's climate system. In addition, one airborne and two portable ground-based radars and other surface sensing systems are available for atmospheric research. Roughly 25% of the funding for NCAR facilities is provided by non-NSF sources. Over 1,500 researchers and students utilize NCAR facilities each year.

#### **National Astronomy Centers**

There are three National Astronomy Centers.

The main facility of the National Astronomy and Ionosphere Center (NAIC) is the 305-meter-diameter radio and radar telescope located at Arecibo, Puerto Rico. NAIC is a visitor-oriented National Research Center devoted to scientific investigations in radio and radar astronomy and atmospheric sciences. NAIC provides telescope users with a wide range of research and observing instrumentation, including receivers, transmitters, movable line feeds, and digital data acquisition and processing equipment.

The National Optical Astronomy Observatories (NOAO) is the national center for research in ground-based optical and infrared astronomy. NOAO includes Kitt Peak National Observatory, Cerro Tololo Inter-American Observatory, and the National Solar Observatory. Large optical telescopes, observing equipment, and research support services are made available to qualified scientists.

The National Radio Astronomy Observatory (NRAO) is headquartered at Charlottesville, Virginia, and operates radio telescopes at three sites. NRAO makes radio astronomy facilities available to qualified visiting scientists and provides staff to help them to use the large radio antennas, receivers, and other equipment needed to detect, measure, and identify radio waves from astronomical objects.

Non-NSF sources provide approximately 7% of the funds for the National Astronomy Centers.

#### **Laser Interferometer Gravitational Wave Observatory (LIGO)**

The LIGO construction project began in FY 1992 as a collaboration between physicists and engineers at the California Institute of Technology and the Massachusetts Institute of Technology to test the dynamical features of Einstein's theory of gravitation and to study the properties of intense gravitational fields from their radiation. LIGO consists of identical, but widely separated detectors (one in Hanford, Washington, and the other in Livingston, Louisiana) that will be used for fundamental physics experiments directly detecting gravitational waves and gathering data on their sources.

### **National High Magnetic Field Laboratory (NHMFL)**

Construction began in FY 1991 on the NHMFL to keep the U.S. at the forefront of high magnetic field research. Research using high magnetic fields has played a key role in the advancement of our knowledge of the physical, chemical, biological and engineering properties of materials. The NHMFL, located at Florida State University, is expected to be fully operational in FY 1995. In FY 1996, the laboratory enters its second five-year development phase, including upgrades of existing magnets and development of next generation magnet systems. Approximately 25% of NHMFL funds are provided by non-NSF sources. In excess of \$100 million has been committed by the State of Florida toward the cost of establishing the laboratory.

### **GEMINI 8-Meter Telescopes**

The Gemini Telescopes Project will construct two 8-meter telescopes, one in Hawaii and one in Chile. Funded through international collaboration, these new generation optical/infrared telescopes have a significantly larger aperture than existing instruments, allowing for better sensitivity, spectral and spatial resolution. The telescope in Hawaii will be operational in FY 1998, and the one in Chile in FY 2000. NSF is providing 50 percent of funding for this project. The \$41 million appropriated in FY 1995 for Gemini completes U.S. funding for this project.

### **National Nanofabrication Users Network**

NSF provides support for research on the fundamental phenomena and processes underlying nanostructures technology and micro-electromechanical systems. To support the national infrastructure needs for these burgeoning research fields, NSF has established the National Nanofabrication Users Network (NNUN), a network of university-based user facilities that will offer advanced nano- and micro-fabrication capabilities to researchers in academe, industry, and government.

### **Academic Research Fleet/Ship Operations**

Oceanographic facilities include ships, submersibles and large shipboard equipment necessary to support NSF-funded research and the training of oceanographers. Twenty-six ships are included in the U.S. academic fleet, operated on behalf of the research community, primarily through NSF funds. Large ships are used for distant-water, expeditionary projects such as global change research; intermediate-sized ships support individual investigator research; and smaller regional ships are available for local and coastal research. Special purpose ships are used for submersible and remotely operated vehicle studies.

### **Academic Research Infrastructure**

The facilities modernization component of the Academic Research Infrastructure program aims to improve the Nation's research infrastructure through focused investment in the revitalization of facilities used for research and research training. Activities encompassed include repair or renovation, or in exceptional cases, replacement of scientific or engineering research and research training facilities. Modernization is focused on facilities at institutions of higher education, independent nonprofit research institutions, and research museums. Assistance is also specifically provided for graduate and undergraduate institutions that historically have received limited Federal research and development funds to enable them to improve their academic science and engineering infrastructure.

### **Polar Facilities**

Polar facilities make research possible in the remote and hazardous Antarctic continent, where all infrastructure must be provided. Three research stations are maintained -- McMurdo, South Pole and Palmer. Other facilities include ski-equipped aircraft, helicopters, research vessels (including a specially constructed ice-breaking research vessel), and an ice-breaking supply and support ship. Logistical support for polar facilities is supplied in part by DOD. Over 600 researchers and students utilize the Antarctic facilities each year. In addition, support for Arctic facilities is provided primarily for research in the geosciences. Arctic facilities include camps and sites for studies of greenhouse gases, monitoring stations for research on ultra-violet radiation, ice coring sites for studies of global climate history, high latitude radar observatories and magnetometers for upper atmospheric research, and the use of a vessel from the academic research fleet, for oceanographic research in the Arctic sea.

## EDUCATION AND TRAINING

The National Science Foundation places a high priority on science, mathematics, engineering, and technology education. These efforts focus on a number of areas related to the *Goals 2000: Educate America Act*:

- enabling U.S. students to become well-informed, scientifically literate citizens
- ensuring an adequate, well-trained workforce
- maintaining U.S. leadership in science and technology

Much of NSF's support is associated with the coordinated, federal interagency effort to improve science, mathematics, engineering and technology education. NSF's programs encompass all education levels: pre-kindergarten through secondary, undergraduate, graduate (both pre- and post-doctoral study), and public science literacy. In addition, special emphasis is placed on groups which have been historically underrepresented in science and engineering fields, namely women, minorities, and persons with disabilities. Other important NSF education and training efforts include programs for evaluation and dissemination, which ensure that education programs achieve their goals and that program and project outcomes reach a wide audience. Education and training totals below include both Education and Human Resources and Research and Related Activities appropriations

(Millions of Dollars)			
	FY 1995 Estimate	FY 1996 Estimate	% Change FY 95 - 96
K-12	371.64	367.81	-1.0%
Undergraduate	147.61	153.36	3.9%
Graduate/Postdoctoral	93.19	93.36	0.2%
Other Education and Training Support	18.03	18.53	2.8%
<b>TOTAL</b>	<b>\$630.47</b>	<b>\$633.06</b>	<b>0.4%</b>

### K-12

The goal of NSF's programs at the K-12 level is for all students to succeed in mathematics, science, and technology. To accomplish this goal, NSF programs are directed at teachers, students, curriculum development, and systemic reform. Teacher enhancement and teacher preparation programs strengthen teachers' knowledge and pedagogical skills and create a network of teachers who are better able to foster reform. The Young Scholars Program recognizes outstanding precollege students and provides research and networking opportunities. K-12 curricula are enhanced through the instructional materials development program. In addition, NSF's systemic reform efforts aim to make lasting improvements in science, mathematics, and technology education at the state level, in urban centers, and in rural regions. The systemic approach involves broad partnerships in the development of goals, solutions, and actions.

The FY 1996 budget request of \$367.81 million is a decrease of \$3.83 million. In FY 1996 support will continue to focus in the following activities: systemic reform (\$95.35 million); teacher preparation and enhancement (\$113.77 million); informal science (\$30.6 million); and in advanced technological education (\$7.8 million).

## Undergraduate

NSF's programs support many facets of undergraduate education, including instrumentation and laboratory improvement, curriculum development, and undergraduate student research. In order to improve the quality of undergraduate courses and curricula in the sciences, NSF provides money to encourage the development of multi- and interdisciplinary courses as well as encourage science, mathematics, and engineering faculty members to take leadership in developing educational experiences that enhance the competence of prospective teachers.

NSF programs which address undergraduate needs include:

- Advanced Technological Education projects, which focus meeting the demands of the competitive, technology-based workplace by targeting technician education programs at the undergraduate and secondary school levels in advanced technology fields and by promoting and supporting curriculum development and program improvement
- Engineering Education Coalitions, which stimulate innovative and comprehensive models for systemic reform of undergraduate engineering education and aim to increase the retention of students,
- Instrumentation and laboratory improvement projects, which develop new or improved laboratory courses or experiments in the sciences and also support matching grants for instructional instrumentation,
- Alliances for Minority Participation, which supports comprehensive approaches to increase the quantity and quality of underrepresented minorities who successfully earn science and engineering baccalaureate degrees, and the number who go on for graduate study in these fields

Undergraduate activities will total \$153.36 million in FY 1996. Engineering Education Coalitions will increase by \$2.55 million in FY 1996 for a total of \$20.0 million. The Advanced Technological Education initiative will remain at the FY 1995 level, for a total of \$15.73 million. The Model Institutions of Excellence, jointly funded across the Foundation, will remain at the FY 1995 level of \$10.0 million. Other undergraduate programs in FY 1996 include support for interdisciplinary mentoring programs for minorities and course and curriculum development.

## Graduate/Postdoctoral

NSF's graduate education programs are designed to improve the human resource base of science and engineering in the United States and to increase the number of minority scientists and engineers who are traditionally underrepresented in advanced levels of science, mathematics, and engineering. Programs include:

- Graduate Fellowships and Minority Graduate Fellowships, which are awarded across all science, mathematics, and engineering disciplines provide financial support for outstanding students during their graduate studies,
- Graduate Research Traineeships, which are awarded competitively to institutions provide student support in critical areas of current and anticipated national priority,
- Research Training Groups, which foster multidisciplinary, research-based training and education at the graduate level,
- Postdoctoral study and research fellowships, which are sponsored in specific research disciplines

Graduate and postdoctoral programs will total \$93.36 million in FY 1996. The graduate research fellowship and graduate research traineeship programs will be sustained at the FY 1995 level. In

addition, increases will include support for postdoctoral fellowships between academic and industrial researchers and international postdoctoral fellows.

#### Other Support for Education and Training

NSF supports programs promoting public interest and literacy in science, mathematics, engineering and technology, including the collection, analysis, and dissemination of data on the education and employment of scientific and technical personnel in the United States. The FY 1996 budget request is \$18.53 million, an increase of \$500,000.

### Integration of Education and Training Activities

In addition to the activities listed above, NSF support of education and training activities is integrated in research projects, facilities and centers. These activities can be characterized as follows:

(Millions of Dollars)				
	FY 1995 Estimate	FY 1996 Estimate	Change	
			Amount	Percent
Young Investigators	86.95	90.55	3.60	4.1%
EPSCoR	36.92	35.91	(1.01)	-2.7%
Undergraduate Research	48.57	51.87	3.30	6.8%
Research for Women and Minorities	12.96	12.46	(0.50)	-3.9%
<b>Total</b>	<b>\$185.40</b>	<b>\$190.79</b>	<b>\$5.39</b>	<b>2.9%</b>

#### Young Investigators

NSF has developed programs to recognize and support scientists and engineers at early stages in their careers. For example, the Faculty Early Development (CAREER) program, begun in FY 1995, supports junior faculty within the context of their overall career development by fostering the integration of research and education. Presidential Faculty Fellow (PFF) awards support the scholarly activities of young science and engineering faculty members by allowing them to undertake self-designed, innovative research and teaching projects, establish research and teaching programs, and pursue other academic-related activities.

Funding for Young Investigators programs total \$90.55 million in FY 1996

#### EPSCoR

The Experimental Program to Stimulate Competitive Research (EPSCoR) is designed to strengthen science and engineering research at academic institutions in participant states. This improvement should increase these states' research capability and their overall research and development competitiveness. The awards assist states and universities in identifying individuals and institutions capable of producing short-term project outcomes and long-term systemic change. Eighteen states and the Commonwealth of Puerto Rico are currently eligible to participate in EPSCoR.

Funding for EPSCoR will be \$35.91 million, a slight decrease from the FY 1995 level

### **Undergraduate Research**

NSF provides additional education and training support in the following undergraduate programs

- Research Experiences for Undergraduates (REU). provides opportunities for undergraduates to gain valuable scientific research experiences,
- Research in Undergraduate Institutions (RUI) provides support for research and research equipment for faculty located in nondoctoral departments in predominately undergraduate institutions,

### **Research for Women and Minorities**

NSF provides additional support in education and training to women and minorities in the following programs

- Visiting Professorships for Women (VPW) supports experienced women scientists and engineers who serve as visiting faculty members at host institutions,
- Faculty Awards for Women (FAW). supports outstanding women faculty with opportunities for advancement into tenured and tenure-track academic positions,
- Research Improvement for Minority Institutions (RIMI): supports projects that strengthen the faculty and student research capabilities and environments.



## INTERDISCIPLINARY RESEARCH AND EDUCATION

Although the disciplinary structure of science and engineering is designed to reflect the underlying order of the natural world, nature in fact knows no disciplinary boundaries. Complex, interdisciplinary problems are the focus of increasing attention, and there are especially rich opportunities at interfaces where disciplines merge. While NSF has a discipline-based organizational structure to facilitate its work, it recognizes the need to ensure that its structure does not create artificial barriers to the support of basic science and engineering that spans more than one area. NSF encourages collaboration and integration across fields of knowledge.

NSF supports interdisciplinary research in keeping with the Foundation's unique role among federal agencies and its long-standing partnership with the academic sector. NSF's activities seek to expand the knowledge base, improve education and training of future scientists, engineers, educators and citizens, stimulate knowledge transfer among academia and the public and private sectors; and enhance components of the infrastructure supporting research and education, including access to the expanded knowledge base.

A critical facet of interdisciplinary and cross-disciplinary activities is the integration of research and education -- a unique strength of the nation's academic system. The Foundation fosters these natural connections through activities that bring out the synergy between research and education, provide incentives for those who want to strengthen the connections, and emphasize the strong bond between learning and inquiry. NSF recognizes the importance both of building a solid understanding and of attending to the formulation and solution of substantive problems. This approach provides the foundation that will allow students to address complex situations they have not previously encountered.

New interdisciplinary activities in research and education are always emerging within the framework of NSF's existing programs. Examples include:

- Optical science and engineering, which promises contributions to many areas of science and technology: in the use of optics and optoelectronics in information and communication, in the control of chemical reaction pathways, in measurements for precision manufacturing, in the elucidation of quantum processes with laser light, and in advances in optical instruments used in research across many fields.
- Multidisciplinary research on human capital, which aims to advance fundamental knowledge about human behavior. Results will provide insights into the experiences and the biological and physical influences that affect the development of people's knowledge, skills and abilities.
- Arctic research, which encompasses all disciplines for studies of Arctic oceans, atmosphere, land areas and their people, plants and wildlife. A special interdisciplinary component, Arctic System Science, focuses on understanding the Arctic region as a complex system of interrelated processes which have global influence -- including a key role in global climate.
- NSF Graduate Research Traineeships, which focus on emerging cross-disciplinary areas critical to the nation's evolving scientific and technological priorities, and encourage innovation in graduate education. For example, a program at the University of Delaware emphasizes the development of an intelligent natural language communication system, involving computer science, linguistics and psychology. Industrial internships and international research opportunities expose trainees to technology applications and to technology being developed in other countries.

- NSF-supported centers, including such activities as Engineering Research Centers and Science and Technology Centers, which address scientific and technical problems that can best be approached through multidisciplinary, long-term coordinated research and education efforts

#### **Basic Research and Education in Interdisciplinary Strategic Areas**

Among the many interdisciplinary frontiers that NSF's programs address are seven "strategic" areas of clear importance to the nation. Strategic areas are selected through a process involving both internal NSF priority setting and a government-wide research and policy process. Within NSF, these areas emerge from planning that takes into account national policy as well as input from the research and education community through reports, workshops and advisory committees. Identification of these areas takes into account such factors as scientific readiness, the availability of infrastructure, and the potential for attracting additional, non-NSF resources. NSF has played an important role in nurturing research in critical areas, which then became the focus of interagency coordination and national efforts.

Basic research in these areas shares the fundamental nature of all activities supported by the Foundation, and incorporates the same standards of quality and expectations for integration of research and education. Funds invested in one area often have a multiplier effect in other areas as well, because of natural connections among them. For example:

- An area of great interest to different disciplines -- and different industries -- is the study of one of nature's greatest feats of engineering, the spider web. Researchers have learned that the silk spun by the golden orb-weaving spider possesses the strength of steel fibers while also being stretchable. The process by which a spider spins silk holds the promise of yielding environmentally-benign manufacturing techniques for industrial fibers. This research crosses the areas of biotechnology, materials and manufacturing.
- Collaborative industry-university research has led to discovery of a new packaging material with valuable properties. A simplified processing method converts liquid crystalline polymer into a new material which has outstanding vapor barrier properties and optical clarity. Before this work, high vapor barrier plastic packaging was made from complex formulations that often lead to difficulties in recycling. This advance is particularly important since the value of polymers used in barrier food packaging was about \$16 billion in 1990. The new material is also being tested for use on underground electric power cables. This research contributes to advances in manufacturing, environment and materials.
- Basic research and education in several strategic areas is increasingly stimulated by advances in high performance computing and communications. In biotechnology, the development of algorithms for molecular dynamics, and the ability to calculate and display molecular structure, have significantly improved understanding of how a new drug may interact with a receptor site. The benefits of high speed networking on science, mathematics, engineering and technology education are just beginning to be explored. One interesting prototype is the Global School House, which can enable shared classroom work in different schools in different countries. Fundamental research in computational geometry can be applied to algorithms for automation, opening new avenues in manufacturing -- virtual prototyping, virtual manufacturing, and laboratories linked across distances.
- Studies in advanced materials and processing make significant contributions across strategic areas -- advances in manufacturing technologies depend on improved materials processes, modern civil infrastructure systems require better structural materials; biotechnology relies on novel biomaterials and bioprocessing techniques, next generation computers and information storage, display and transmission devices will result from new electronic and photonic

materials, and environmental concerns are addressed by the development of benign materials.

Such connections and collaborations effectively allow the Foundation to coordinate the allocation of its resources and to increase the return of its investment in strategic areas.

Identification of strategic areas continues to evolve, including the recent integration of the Environment area with the Global Change area to enhance mutually beneficial research and education activities. In FY 1996, NSF will fund basic research and education activities in support of the following seven areas:

(Millions of Dollars)

	FY 1995	FY 1996	Percent
	Estimate	Estimate	Change
Advanced Materials and Processing Program	213.32	226.12	6.0%
Biotechnology	166.33	176.65	6.2%
Civil Infrastructure Systems	54.50	57.27	5.1%
Environment and Global Change	329.47	355.56	7.9%
High Performance Computing and Communications	296.94	313.64	5.6%
Manufacturing	128.42	136.39	6.2%
Science, Math, Engineering and Technology Education	647.27	656.03	1.4%

Funding shown for each strategic area is mutually exclusive

**Advanced Materials and Processing Program (AMPP)** totals \$226.12 million, an increase of \$12.80 million, or 6.0 percent, over FY 1995. The overall goals of AMPP are to enhance the fundamental understanding of materials, develop appropriate university-industry research partnerships, and to provide interdisciplinary education and training to prepare future scientists and engineers for careers in academia, government, and industry.

AMPP has three objectives:

- synthesize novel materials with desirable properties;
- advance understanding of the behavior and properties of materials, and
- develop processes to produce, modify, and shape materials.

AMPP provides an improved understanding of interrelationships among synthesis and processing, structure and composition, properties, and performance of materials. AMPP supports individual and small group projects, interdisciplinary centers and user facilities, as well as major instrumentation for shared use. AMPP fosters interagency collaborations and promotes materials-related activities through university-industry-government consortia.

The FY 1996 estimate includes additional support for:

- design and synthesis of new classes of materials with predictable and desirable properties, nano science and engineering aimed at achieving control of the fabrication and processing of electronic and optical structures at atomic and molecular levels; synthesis of new materials that mimic properties found in biological materials, and development of smart materials that respond to changes in their environment,

- upgrade of user facilities and development of characterization and processing equipment; and
- an increase in industry-university collaborations; development of new partnerships with other federal agencies and National Laboratories; and international workshops to identify materials research areas that benefit participating countries.

**Biotechnology** funding totals \$176.65 million, an increase of \$10.32 million or 6.2 percent, over FY 1995. The goals for NSF biotechnology research are to increase understanding at the most basic biological level, and to develop the infrastructure and human resources for continued progress in biotechnology. Special emphasis is given to multidisciplinary research in key areas.

Priorities for biotechnology research are

- environmental biotechnology;
- bioprocessing/bioconversion; and
- plant/agricultural biotechnology.

The tools and approaches of biotechnology now promise solutions to problems in the areas of the environment, agriculture, and bioprocessing. However, knowledge in these areas remains poorly developed. For example, studies involving marine organisms and studies of the social and economic dimensions of biotechnology are particularly needed. A new level of multidisciplinary effort is required, spanning the interfaces of traditional disciplines. Increased funding will enable support of new collaborations focused on the special emphasis areas, and will have a substantial impact on the development of the knowledge and human resource base.

Specific goals in priority areas include:

- search for novel organisms and identify biochemical pathways useful for prevention of pollution, detection of environmental stress, and for environmental rehabilitation;
- study the metabolic pathways used by a wide range of organisms and cell types to produce products, and elucidate the regulation of these pathways so that they can ultimately be engineered to optimize the synthesis of desired substances; and
- support research that will contribute to a complete understanding of the biology of plants so that it will be possible to engineer economically advantageous traits.

**Civil Infrastructure Systems (CIS)** totals \$57.27 million, an increase of \$2.77 million, or 5.1 percent, over FY 1995. In supporting CIS research and education, NSF seeks to create new scientific and engineering knowledge that can advance the understanding, assessment and intelligent renewal of civil infrastructure systems. Ongoing activities support an integrated multidisciplinary effort in the following areas:

- deterioration science, which examines how materials and structures break down and wear out;
- assessment technologies, which determine how durable, safe and environmentally benign our structures and facilities are;
- renewal engineering, which extends and enhances the life of infrastructure systems and components that would otherwise continue to deteriorate; and

- institutional effectiveness and productivity, which seeks to understand the social, management and economic barriers to the most effective construction and replacement of civil infrastructure.

The FY 1996 effort will expand research on:

- processing and design methods for new materials and engineering systems with intelligence, adaptivity, and low life-cycle cost;
- superior sensing, actuating and self-repair or self-recovery capabilities in materials for large-scale applications in buildings and transportation, power, water distribution, and communications systems; and
- new integrated approaches and new techniques to mitigate seismic hazard with emphasis on the reduction of disruption and the induced economic losses of urban lifelines systems.

**Environment and Global Change (EGC)** research totals \$355.56 million, an increase of \$26.09 million, or 7.9 percent, over FY 1995. The goals of environmental and global change research are to enhance understandings of the complex dynamics among natural and human systems; to generate knowledge needed to preserve, manage, and enhance the environment, and to provide scientific background for national and international policy-making activities.

Specific long-term goals of NSF environment and global change research programs include:

- improve models that can be used for more accurate predictions of short-term climate fluctuations, such as the El Niño phenomenon, and longer-term environmental changes, such as depletion of stratospheric ozone and climate warming,
- acquire additional information about biodiversity and ecosystem function through expanded biological surveys and inventories, and research aimed at understanding the role of species in ecosystem processes and sustainability,
- develop more environmentally conscious design and manufacturing systems, remediation and restoration techniques, and new environmental technologies, and
- increase understanding of physical processes that underlie natural hazards; improve hazard prediction and forecasting methodologies, warning, evacuation, and response systems, and methods to assess risk, damage, and cost-mitigation.

In FY 1996, special attention will focus on:

- biodiversity and ecosystem function, and terrestrial ecology, to understand the role of biodiversity in ecological systems and the sensitivity of ecosystems to changes from multiple interacting factors,
- interdisciplinary science and engineering research that takes an integrated systems approach to water and watersheds;
- environmental technology focused on environmentally benign synthesis and processing, and research related to natural hazard reduction;
- major international field-based data-collection programs on global change, and expanded capabilities for developing and testing climate system models; and

- research on new approaches for examining complex interactions among earth's physical, biological and human systems, in ways that assist policy makers, and fundamental studies of decision-making processes related to environmental policies.

**High Performance Computing and Communications (HPCC)** totals \$313.64 million, an increase of \$16.70 million, or 5.6 percent, over FY 1995. NSF is a key element of the federal program to extend U.S. technological leadership in high performance computing and communications, accelerate wide dissemination and application of technologies to speed the pace of innovation, and spur gains in U.S. productivity and industrial competitiveness through the use of high performance computing and networking technologies. NSF's HPCC objectives include:

- generate fundamental knowledge with the potential to radically change the state of high performance computing and communication, and create a cadre of scientists, engineers, and technical personnel prepared to exploit these new capabilities;
- establish interdisciplinary teams to create innovative technologies in computation and communication that support national technical and societal goals, and encourage partnerships to enhance innovation, technology transfer and U.S. productivity and industrial competitiveness;
- introduce new generations of scalable parallel high performance computers and software technologies, and develop very high speed national research and education networking services and capabilities for connecting universities, high schools, research laboratories, and libraries; and
- support fundamental research to make advanced computing and communications information infrastructure available to a larger segment of the society

HPCC balances support for individual investigators performing fundamental disciplinary research; multidisciplinary research teams studying broad scientific and national problems; Science and Technology Centers targeted on major, significant research areas; deployment of networking services, access to specialized high performance computing and communication capabilities, and exploring new opportunities and technologies for enhancing science and engineering education.

The emphasis areas in FY 1996 include

- expand software and algorithm research for scalable, parallel systems and for heterogeneous interoperable systems;
- expand capability and access to very high speed backbone network services for research on Grand and National Challenge application problems;
- enhance processing power at the NSF supercomputer centers, and further broadening cooperative activities with other centers,
- develop a coordinated, multidisciplinary research and prototype activity to advance capabilities for creation and use of massive knowledge repositories; and
- increase research on emerging technologies for very large, reliable, high performance, distributed prototype information systems potentially applicable to 21st century scientific research and education.

**Manufacturing** totals \$136.39 million, an increase of \$7.97 million, or 6.2 percent, over FY 1995. Research supported in manufacturing aims to improve and refine the current state of fundamental

knowledge upon which manufacturing processes and techniques depend. Specific long-term goals include:

- next generation "intelligent" manufacturing systems that will require electronic commerce and flexible business and management structures for rapidly reconfigurable, highly automated, integrated production;
- integrated tools for product, process, and enterprise design that allow the simultaneous evaluation of the impact of changes in product design, manufacturing, delivery, and servicing;
- fundamental breakthroughs in "infrastructure" technologies, such as sensors, process modeling, computation and control, global economics, and technology management, which are needed to enable the development and effective implementation of next generation "intelligent" manufacturing systems; and
- environmentally conscious manufacturing technologies to make manufacturing's effect on the natural environment more benign, such as developing resource- and energy-efficient design methodologies and production processes.

NSF is working with a multi-agency team to advance manufacturing education and training to produce world-class practitioners. The NSF effort addresses the need for systemic reform in engineering education, focusing on engineering synthesis and a team approach to design and manufacturing.

In FY 1996, special attention will be given to:

- virtual and physical rapid prototyping;
- the development of advanced sensors and controls for intelligent manufacturing systems;
- advanced fabrication and processing methods; and
- research on environmentally conscious design and manufacturing.

**Science, Mathematics, Engineering, and Technology Education (SMETE)** totals \$656.03 million, an overall increase of \$8.76 million, or 1.4 percent, over FY 1995, following strong growth in recent years. NSF's mandate includes responsibility for science, mathematics, engineering and technology education. The Foundation provides leadership in the interagency effort to reform education. Consonant with four of the National Education Goals recently framed in *Goals 2000: Educate America Act*, SMETE's long-term goals are to:

- improve science, mathematics and engineering performance for all U.S. learners at all educational levels;
- ensure that U.S. precollege students will be first in the world in science and mathematics achievement,
- ensure both a strong elementary, secondary, and postsecondary instructional workforce and technical workforce; and
- improve public science literacy.

To achieve these goals, NSF is working to strengthen partnerships with industry, state and local governments, and with schools, colleges and universities throughout the country. As part of an

interagency effort, NSF is committed to providing the citizenry with the knowledge and skills needed to meet the demands of the high-technology jobs of the future.

In FY 1996, continued emphasis will be on:

- systemic reform in elementary and secondary education at the state, urban and rural levels, and for activities that support reform -- such as professional development of teachers, and development of instructional materials and curricula that conform to mathematics and science standards;
- informal science education; advanced technological education; undergraduate course and curriculum development;
- human resource development and full participation of underrepresented groups; and
- development of scientific competency through undergraduate, graduate, postdoctoral and faculty research experiences.



## NSF FUNDING PROFILE

Approximately half of the awards that are supported in a particular fiscal year are competitively reviewed in that year through NSF's merit review process. The other awards are continuations of projects that were competitively reviewed in a prior year. The funding rate is the number of competitive awards made during a year as a percentage of total proposals competitively reviewed. It indicates the probability of winning an award when submitting proposals to NSF.

The annualized award size displays the annual level of support provided to awardees by dividing the total dollars of each award by the number of years over which it extends. Both the average and the median annualized award size for competitively reviewed awards are shown.

Average duration is the length of the award in years. The duration calculation is limited to research projects and excludes other categories of awards which fund infrastructure-type activities such as equipment and conference awards which do not require multi-year support.

The Quantitative Data Tables provided under a separate tab are based on all proposals and awards, including competitive awards, contracts, cooperative agreements, supplements and amendments to existing grants and contracts.

### NSF FUNDING PROFILE

	FY 1994 Estimate	FY 1995 Estimate	FY 1996 Estimate
Total Number of Awards	19,346	19,819	20,362
Statistics for Competitive Awards			
Number	10,300	10,600	10,900
Funding Rate	32%	32%	32%
Median Annualized Award Size <sup>1</sup>	\$55,977	\$58,200	\$61,100
Average Annualized Award Size <sup>1</sup>	\$71,144	\$74,000	\$77,700
Average Duration (yrs.) <sup>1</sup>	2.6	2.7	2.8

<sup>1</sup>Statistics for average award size and duration for Research Projects only. Excludes facilities, centers, fellowships, and travel.

**LEVEL OF FUNDING BY PROGRAM**

PROGRAM ELEMENT	(Dollars in Thousands)				CHANGE	
	FY 1994 ACTUAL	FY 1995 REQUEST	FY 1995 CURRENT PLAN	FY 1996 REQUEST	FY 96 Req/FY 95 CP AMOUNT	PERCENT
<b><u>BIOLOGICAL SCIENCES</u></b>						
<i>MOLECULAR AND CELLULAR BIOSCIENCES</i>						
Biochemistry and Molecular						
Structure and Function	\$34,018	\$36,050	\$35,000	\$37,110	\$2,110	6.0%
Cell Biology	20,130	21,450	20,840	22,340	1,500	7.2%
Genetics and Nucleic Acids	30,742	33,550	32,180	34,720	2,540	7.9%
<b>Total</b>	<b>84,890</b>	<b>91,050</b>	<b>88,020</b>	<b>94,170</b>	<b>6,150</b>	<b>7.0%</b>
<i>INTEGRATIVE BIOLOGY AND NEUROSCIENCES</i>						
Physiology and Behavior	29,464	33,310	31,000	33,110	2,110	6.8%
Neuroscience	32,416	33,100	33,700	35,890	2,190	6.5%
Developmental Biology	15,690	17,310	16,200	17,330	1,130	7.0%
<b>Total</b>	<b>77,570</b>	<b>83,720</b>	<b>80,900</b>	<b>86,330</b>	<b>5,430</b>	<b>6.7%</b>
<i>ENVIRONMENTAL BIOLOGY</i>						
Systematic and Population Biology	22,469	26,040	24,270	26,380	2,110	8.7%
Ecological Studies	26,582	27,960	27,920	29,980	2,060	7.4%
Long-term Projects in Environmental Biology	25,249	29,300	26,450	28,970	2,520	9.5%
<b>Total</b>	<b>74,300</b>	<b>83,300</b>	<b>78,640</b>	<b>85,330</b>	<b>6,690</b>	<b>8.5%</b>
<i>BIOLOGICAL INSTRUMENTATION AND RESOURCES</i>						
Instrumentation and						
Instrument Development	14,976	15,790	14,100	14,660	560	4.0%
Special Projects	36,143	40,080	39,290	43,470	4,180	10.6%
<b>Total</b>	<b>51,119</b>	<b>55,870</b>	<b>53,390</b>	<b>58,130</b>	<b>4,740</b>	<b>8.9%</b>
<b>Total, BIO</b>	<b>\$287,879</b>	<b>\$313,940</b>	<b>\$300,950</b>	<b>\$323,960</b>	<b>\$23,010</b>	<b>7.6%</b>

**LEVEL OF FUNDING BY PROGRAM (continued)**

(Dollars in Thousands)						
PROGRAM ELEMENT	FY 1994 ACTUAL	FY 1993 REQUEST	FY 1993 CURRENT PLAN	FY 1996 REQUEST	CHANGE FY 96 Req/FY 93 CP AMOUNT	PERCENT
<b>COMPUTER AND INFORMATION SCIENCE AND ENGINEERING</b>						
<i>COMPUTER AND COMPUTATION RESEARCH</i>						
Theory of Computing	\$9,394	\$10,150	\$9,765	\$10,340	\$575	5.9%
Numeric, Symbolic & Geometric Computation	7,322	7,720	7,510	8,010	500	6.7%
Computer Systems	4,305	4,500	4,375	4,620	245	5.6%
System Software	13,152	14,000	13,350	14,310	960	7.2%
Software Engineering	4,929	5,540	5,260	5,630	370	7.0%
<b>Total</b>	<b>39,102</b>	<b>41,910</b>	<b>40,260</b>	<b>42,910</b>	<b>2,650</b>	<b>6.6%</b>
<i>INFORMATION, ROBOTICS AND INTELLIGENT SYSTEMS</i>						
Knowledge and Database System	12,670	14,780	13,980	15,130	1,150	8.2%
Robotics and Machine Intelligence	6,475	8,350	7,100	7,400	300	4.2%
Interactive Systems	4,843	5,900	5,600	6,300	700	12.5%
Information Technology and Organizations	5,594	5,700	5,600	6,300	700	12.5%
<b>Total</b>	<b>29,582</b>	<b>34,730</b>	<b>32,280</b>	<b>35,130</b>	<b>2,850</b>	<b>8.8%</b>
<i>MICROELECTRONIC INFORMATION PROCESSING SYSTEMS</i>						
Design, Tools and Test	4,394	5,140	4,840	5,230	390	8.1%
Microelectronic Systems Architecture	4,096	4,770	4,500	4,830	330	7.3%
Circuits and Signal Processing	4,354	4,950	4,770	5,100	330	6.9%
Experimental Systems	7,681	9,120	8,320	8,970	650	7.8%
Systems Prototyping and Fabrication	3,011	3,600	3,400	4,010	610	17.9%
<b>Total</b>	<b>23,536</b>	<b>27,580</b>	<b>25,830</b>	<b>28,140</b>	<b>2,310</b>	<b>8.9%</b>
<i>ADVANCED SCIENTIFIC COMPUTING</i>						
Centers	69,736	78,470	73,460	77,460	4,000	5.4%
New Technologies	4,875	6,700	5,750	6,600	850	14.8%
<b>Total</b>	<b>74,611</b>	<b>85,170</b>	<b>79,210</b>	<b>84,060</b>	<b>4,850</b>	<b>6.1%</b>
<i>NETWORKING AND COMMUNICATIONS RESEARCH AND INFRASTRUCTURE</i>						
NSFNET	39,113	46,660	45,220	46,220	1,000	2.2%
Networking & Communications Research	10,830	11,600	11,240	13,340	2,100	18.7%
<b>Total</b>	<b>49,943</b>	<b>58,260</b>	<b>56,460</b>	<b>59,560</b>	<b>3,100</b>	<b>5.5%</b>
<i>CROSS-DISCIPLINARY ACTIVITIES</i>						
CISE Institutional Infrastructure	19,588	21,890	20,670	22,210	1,540	7.5%
CISE Instrumentation	3,163	3,960	3,560	3,560	0	0.0%
<b>Total</b>	<b>22,751</b>	<b>25,850</b>	<b>24,230</b>	<b>25,770</b>	<b>1,540</b>	<b>6.4%</b>
<b>Total, CISE</b>	<b>\$239,525</b>	<b>\$273,500</b>	<b>\$258,270</b>	<b>\$275,570</b>	<b>\$17,300</b>	<b>6.7%</b>

## LEVEL OF FUNDING BY PROGRAM (continued)

(Dollars in Thousands)						
PROGRAM ELEMENT	FY 1994 ACTUAL	FY 1995 REQUEST	FY 1995 CURRENT PLAN	FY 1996 REQUEST	CHANGE FY 96 Req FY 95 CP AMOUNT	PERCENT
<b>ENGINEERING</b>						
<i>BIOENGINEERING AND ENVIRONMENTAL SYSTEMS</i>						
Bioengineering	\$15,630	\$17,100	\$16,400	\$17,940	\$1,540	9.4%
Environmental and Ocean Systems	6,265	6,430	\$7,030	7,630	600	8.5%
<b>Total</b>	<b>21,895</b>	<b>23,530</b>	<b>23,430</b>	<b>25,570</b>	<b>2,140</b>	<b>9.1%</b>
<i>CHEMICAL AND TRANSPORT SYSTEMS</i>						
Chemical Reaction Processes	9,952	10,200	10,200	10,760	560	5.5%
Interfacial, Transport and Separations Processes	9,033	9,560	9,560	10,010	450	4.7%
Fluid, Particulate and Hydraulic Systems	9,731	10,210	10,210	10,860	650	6.4%
Thermal Systems	7,850	8,400	8,480	9,500	1,020	12.0%
<b>Total</b>	<b>36,566</b>	<b>38,370</b>	<b>38,450</b>	<b>41,130</b>	<b>2,680</b>	<b>7.0%</b>
<i>CIVIL AND MECHANICAL SYSTEMS</i>						
Earthquake Hazard Mitigation	14,995	16,230	16,880	18,100	1,220	7.2%
Natural and Technological Hazard Mitigation	2,560	2,830	2,870	3,070	200	7.0%
Dynamic Systems and Control	4,311	4,390	4,450	4,750	300	6.7%
Structures, Geomechanics and Building Systems	9,315	10,100	11,000	12,000	1,000	9.1%
Surface Engineering and Technology	2,744	2,970	3,050	3,270	220	7.2%
Mechanics and Materials	9,512	10,100	10,120	10,700	580	5.7%
<b>Total</b>	<b>43,437</b>	<b>46,620</b>	<b>48,370</b>	<b>51,890</b>	<b>3,520</b>	<b>7.3%</b>
<i>DESIGN, MANUFACTURE, AND INDUSTRIAL INNOVATION</i>						
Operations Research and Production Systems	6,280	7,950	8,050	8,770	720	8.9%
Design and Integration Engineering	15,753	7,860	7,960	8,700	740	9.3%
Manufacturing Processes and Equipment	12,374	15,040	15,240	16,600	1,360	8.9%
Small Business Innovation Research	30,613	42,310	40,800	43,740	2,940	7.2%
Management of Technological Innovation	1,253	1,500	1,500	1,750	250	16.7%
Special Studies and Assessments	1,336	1,400	1,400	2,200	800	57.1%
Industry/University Liaison	2,423	3,800	3,700	6,300	2,600	70.3%
<b>Total</b>	<b>70,032</b>	<b>79,860</b>	<b>78,650</b>	<b>88,060</b>	<b>9,410</b>	<b>12.0%</b>
<i>ELECTRICAL AND COMMUNICATIONS SYSTEMS</i>						
Quantum Electronics, Waves and Beams	9,565	10,590	10,120	11,010	890	8.8%
Solid State and Microstructures	11,197	11,770	11,720	12,460	740	6.3%
Communications and Computational Systems	6,938	7,840	7,485	7,945	460	6.1%
Engineering Systems	8,930	9,150	9,525	10,265	740	7.8%
<b>Total</b>	<b>36,630</b>	<b>39,350</b>	<b>38,850</b>	<b>41,680</b>	<b>2,830</b>	<b>7.3%</b>
<i>ENGINEERING EDUCATION AND CENTERS</i>						
Engineering Education	18,286	21,800	22,100	25,150	3,050	13.8%
Human Resources Development	11,021	11,530	10,100	10,100	0	0.0%
Engineering Research Centers	51,375	51,500	51,730	52,430	700	1.4%
Industry/University Cooperative Research Centers	7,484	7,850	7,850	8,150	300	3.8%
<b>Total</b>	<b>88,166</b>	<b>92,680</b>	<b>91,780</b>	<b>95,830</b>	<b>4,050</b>	<b>4.4%</b>
<b>Total, ENG</b>	<b>\$296,726</b>	<b>\$320,410</b>	<b>\$319,530</b>	<b>\$344,160</b>	<b>\$24,630</b>	<b>7.7%</b>

**LEVEL OF FUNDING BY PROGRAM (continued)**

	(Dollars in Thousands)					
PROGRAM ELEMENT	FY 1994 ACTUAL	FY 1995 REQUEST	FY 1995 CURRENT PLAN	FY 1996 REQUEST	CHANGE FY 96 Req/FY 95 CP AMOUNT	PERCENT
<b>GEOSCIENCES</b>						
<i>ATMOSPHERIC SCIENCES</i>						
Atmospheric Sciences Research Support	\$81,956	\$91,380	\$85,430	\$91,010	\$5,580	6.5%
National Center for Atmospheric Research	52,505	56,490	58,380	64,830	6,450	11.0%
<b>Total</b>	<b>134,461</b>	<b>147,870</b>	<b>143,810</b>	<b>155,840</b>	<b>12,030</b>	<b>8.4%</b>
<i>EARTH SCIENCES</i>						
Earth Sciences Project Support	52,911	57,660	54,490	58,570	4,080	7.5%
Instrumentation and Facilities	20,595	21,760	20,430	22,150	1,720	8.4%
Continental Dynamics	7,162	7,870	7,390	9,330	1,940	26.3%
<b>Total</b>	<b>80,668</b>	<b>87,290</b>	<b>82,310</b>	<b>90,050</b>	<b>7,740</b>	<b>9.4%</b>
<i>OCEAN SCIENCES</i>						
Ocean Sciences Research Support	99,209	113,980	102,900	110,300	7,400	7.2%
Oceanographic Centers and Facilities	51,131	53,950	50,600	54,200	3,600	7.1%
Ocean Drilling Program	38,690	40,000	39,870	41,090	1,220	3.1%
<b>Total</b>	<b>189,030</b>	<b>207,930</b>	<b>193,370</b>	<b>205,590</b>	<b>12,220</b>	<b>6.3%</b>
<b>Total, GEO</b>	<b>\$404,159</b>	<b>\$443,090</b>	<b>\$419,490</b>	<b>\$451,480</b>	<b>\$31,990</b>	<b>7.6%</b>

**LEVEL OF FUNDING BY PROGRAM (continued)**

	(Dollars in Thousands)					
PROGRAM ELEMENT	FY 1994 ACTUAL	FY 1995 REQUEST	FY 1995 CURRENT PLAN	FY 1996 REQUEST	CHANGE FY 96 Req/FY 95 (P AMOUNT PERCENT	
<b><u>MATHEMATICAL AND PHYSICAL SCIENCES</u></b>						
<i>MATHEMATICAL SCIENCES</i>						
Research Project Support	\$62,070	\$65,970	\$65,220	\$70,310	\$5,090 7.8%	
Infrastructure Support	15,974	18,610	18,400	19,550	1,150 6.3%	
<b>Total</b>	<b>78,044</b>	<b>84,580</b>	<b>83,620</b>	<b>89,860</b>	<b>6,240 7.5%</b>	
<i>ASTRONOMICAL SCIENCES</i>						
Astronomy Research Project Support	39,000	40,520	38,800	40,000	1,200 3.1%	
National Astronomy & Ionosphere Center	8,250	8,170	7,820	8,580	760 9.7%	
National Optical Astronomy Observatories	26,490	27,880	26,690	29,230	2,540 9.5%	
National Radio Astronomy Observatory	27,762	30,150	28,870	32,580	3,710 12.9%	
<b>Total</b>	<b>101,502</b>	<b>106,720</b>	<b>102,180</b>	<b>110,390</b>	<b>8,210 8.0%</b>	
<i>PHYSICS</i>						
Physics Research Project Support	95,326	97,030	93,580	98,950	5,370 5.7%	
Facilities	32,100	38,110	36,750	43,250	6,500 17.7%	
<b>Total</b>	<b>127,426</b>	<b>135,140</b>	<b>130,330</b>	<b>142,200</b>	<b>11,870 9.1%</b>	
<i>CHEMISTRY</i>						
Chemistry Research Project Support	97,010	105,790	105,110	112,900	7,790 7.4%	
Instrumentation & Infrastructure	17,920	18,070	17,950	20,740	2,790 15.5%	
<b>Total</b>	<b>114,930</b>	<b>123,860</b>	<b>123,060</b>	<b>133,640</b>	<b>10,580 8.6%</b>	
<i>MATERIALS RESEARCH</i>						
Materials Research Project Support	79,179	83,770	83,080	88,970	5,890 7.1%	
Materials Research Science and Engineering Centers	55,100	59,410	58,920	62,320	3,400 5.8%	
National Facilities and Instrumentation	32,879	33,660	33,380	39,630	6,250 18.7%	
<b>Total</b>	<b>167,158</b>	<b>176,840</b>	<b>175,380</b>	<b>190,920</b>	<b>15,540 8.9%</b>	
<i>OFFICE OF MULTIDISCIPLINARY ACTIVITIES</i>						
Research Project Support	28,820	30,580	30,000	31,270	1,270 4.2%	
<b>Total</b>	<b>28,820</b>	<b>30,580</b>	<b>30,000</b>	<b>31,270</b>	<b>1,270 4.2%</b>	
<b>Total, MPS</b>	<b>\$617,880</b>	<b>\$657,720</b>	<b>\$644,570</b>	<b>\$698,280</b>	<b>53,710 8.3%</b>	

## LEVEL OF FUNDING BY PROGRAM (continued)

(Dollars in Thousands)						
PROGRAM ELEMENT	FY 1994 ACTUAL	FY 1995 REQUEST	FY 1995 CURRENT PLAN	FY 1996 REQUEST	CHANGE FY 96 Req/FY 95 CP AMOUNT	PERCENT
<b><u>SOCIAL, BEHAVIORAL AND ECONOMIC SCIENCES</u></b>						
<i>SOCIAL, BEHAVIORAL AND ECONOMIC RESEARCH</i>						
Social, Behavioral and Economic Research	\$70,599	\$83,970	\$84,900	\$91,690	\$6,790	8.0%
<b>Total</b>	<b>70,599</b>	<b>83,970</b>	<b>84,900</b>	<b>91,690</b>	<b>6,790</b>	<b>8.0%</b>
<i>INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES</i>						
International Cooperative Scientific Activities	15,790	16,710	16,960	18,750	1,790	10.6%
<b>Total</b>	<b>15,790</b>	<b>16,710</b>	<b>16,960</b>	<b>18,750</b>	<b>1,790</b>	<b>10.6%</b>
<i>SCIENCE RESOURCES STUDIES</i>						
Science Resource Studies	11,821	11,930	11,930	12,430	500	4.2%
<b>Total</b>	<b>11,821</b>	<b>11,930</b>	<b>11,930</b>	<b>12,430</b>	<b>500</b>	<b>4.2%</b>
<b>Total, SBE</b>	<b>\$98,210</b>	<b>\$112,610</b>	<b>\$113,790</b>	<b>\$122,870</b>	<b>\$9,080</b>	<b>8.0%</b>

## LEVEL OF FUNDING BY PROGRAM (continued)

PROGRAM ELEMENT	(Dollars in Thousands)		FY 1995 CHIEF OF PLAN	FY 1996 REQUEST	CHANGE	
	FY 1994 ACTUAL	FY 1995 REQUEST			FY 96 Request vs FY AMOUNT	FY 96 PERCENT
UNITED STATES POLAR RESEARCH PROGRAMS	\$158,377	\$162,830	\$158,800	\$172,280	\$13,480	8.5%
UNITED STATES ANTARCTIC LOGISTICAL SUPPORT ACTIVITIES	\$64,100 <sup>1</sup>	\$62,000	\$62,000	\$62,600	\$0	0.0%
CRITICAL TECHNOLOGIES INSTITUTE	\$1,500	\$2,000	\$2,000	\$2,800	\$3,000	40.0%
MAJOR RESEARCH EQUIPMENT <sup>4</sup>	[\$17,043] <sup>2</sup>	\$0	\$0	\$0	NA	NA
Subtotal, RESEARCH AND RELATED ACTIVITIES	\$2,168,356	\$2,348,700	\$2,280,800	\$2,454,000	174,000	7.6%
Carryover <sup>3</sup>			2,897		(2,897)	100.0%
Total, RESEARCH AND RELATED ACTIVITIES	\$2,168,356	\$2,348,700	\$2,282,897	\$2,454,000	\$171,103	7.5%



**LEVEL OF FUNDING BY PROGRAM (continued)**

PROGRAM ELEMENT	(Dollars in Thousands)		FY 1995 CURRENT PLAN	FY 1996 REQUEST	CHANGE	
	FY 1994 ACTUAL	FY 1995 REQUEST			FY 96 Req/FY 95 CP AMOUNT	PERCENT
<b>EDUCATION AND HUMAN RESOURCES</b>						
<i>EDUCATIONAL SYSTEM REFORM</i>						
Educational System Reform	\$80,312	\$86,260	\$96,444	\$95,350	(\$1,094)	-1.1%
<b>Total</b>	<b>\$80,312</b>	<b>\$86,260</b>	<b>\$96,444</b>	<b>\$95,350</b>	<b>(\$1,094)</b>	<b>-1.1%</b>
<i>EXPERIMENTAL PROGRAM TO STIMULATE COMPETITIVE RESEARCH (EPSCoR)</i>						
Experimental Program to Stimulate Competitive Research	31,051	31,920	36,920	35,910	(1,010)	-2.7%
<b>Total</b>	<b>31,051</b>	<b>31,920</b>	<b>36,920</b>	<b>35,910</b>	<b>(1,010)</b>	<b>-2.7%</b>
<i>ELEMENTARY, SECONDARY AND INFORMAL EDUCATION</i>						
Student Support	11,082	11,000	10,000	10,000	0	0.0%
Curriculum Development	44,848	48,480	48,780	48,180	(600)	-1.2%
Teacher Enhancement & Development	108,184	105,000	100,970	99,970	(1,000)	-1.0%
Informal Science Education	34,567	35,000	36,000	36,000	0	0.0%
<b>Total</b>	<b>198,681</b>	<b>199,480</b>	<b>195,750</b>	<b>194,150</b>	<b>(1,600)</b>	<b>-0.8%</b>
<i>UNDERGRADUATE EDUCATION</i>						
Curriculum & Laboratory Development	54,993	57,210	59,150	58,600	(550)	-0.9%
Teacher and Faculty Development	23,520	26,000	25,100	24,830	(270)	-1.1%
<b>Total</b>	<b>78,513</b>	<b>83,210</b>	<b>84,250</b>	<b>83,430</b>	<b>(820)</b>	<b>-1.0%</b>
<i>GRADUATE EDUCATION</i>						
Graduate Student Support	59,206	63,390	66,790	66,790	0	0.0%
<b>Total</b>	<b>59,206</b>	<b>63,390</b>	<b>66,790</b>	<b>66,790</b>	<b>0</b>	<b>0.0%</b>
<i>HUMAN RESOURCE DEVELOPMENT</i>						
Precollege Education (ACCESS)	15,370	15,030	16,280	15,830	(450)	-2.8%
Undergraduate Student Support	25,576	25,510	26,410	26,410	0	0.0%
Research & Education Infrastructure	14,999	15,450	15,790	14,540	(1,250)	-7.9%
Opportunities for Women and Persons with Disabilities	18,637	18,270	18,270	18,020	(250)	-1.4%
<b>Total</b>	<b>74,582</b>	<b>74,260</b>	<b>76,750</b>	<b>74,800</b>	<b>(1,950)</b>	<b>-2.5%</b>
<i>RESEARCH, EVALUATION AND COMMUNICATIONS</i>						
Research	14,265	13,440	13,030	13,030	0	0.0%
Evaluation	8,324	10,270	10,270	10,270	0	0.0%
Technology Utilization	24,099	23,770	25,770	25,270	(500)	-1.9%
<b>Total</b>	<b>46,688</b>	<b>47,480</b>	<b>49,070</b>	<b>48,570</b>	<b>(500)</b>	<b>-1.0%</b>
<b>Subtotal, EHR</b>	<b>569,033</b>	<b>586,000</b>	<b>605,974</b>	<b>599,000</b>	<b>(6,974)</b>	<b>-1.2%</b>
<b>Carryover</b>			<b>8,057</b>		<b>(8,057)</b>	<b>-100.0%</b>
<b>Total, EHR</b>	<b>\$569,033</b>	<b>\$586,000</b>	<b>\$614,031</b>	<b>\$599,000</b>	<b>(\$15,031)</b>	<b>-2.4%</b>

## LEVEL OF FUNDING BY PROGRAM (continued)

PROGRAM ELEMENT	(Dollars in Thousands)					CHANGE FY 96 Req/FY 95 CP AMOUNT PERCENT
	FY 1994 ACTUAL	FY 1995 REQUEST	FY 1995 CURRENT PLAN	FY 1996 REQUEST		
ACADEMIC RESEARCH INFRASTRUCTURE Proposed Rescission	\$105,377	\$55,000	\$250,000 (\$131,867)	\$100,000	(\$150,000)	-60.0%
Subtotal, ARI	\$105,377	\$55,000	\$118,133	\$100,000	(\$18,133)	-15.3%
Carryover	0	0	243	0	-243	-100.0%
Total, ARI	\$105,377	\$55,000	\$118,376	\$100,000	(\$18,376)	-15.5%
MAJOR RESEARCH EQUIPMENT <sup>1</sup>	\$17,043 <sup>2</sup>	\$70,000	\$126,000	\$70,000	(\$56,000)	-44.4%
SALARIES AND EXPENSES	\$118,290	\$130,720	\$123,966	\$127,310	\$3,344	2.7%
NSF HEADQUARTERS RELOCATION	\$5,200	\$5,200	\$5,200	\$5,200	\$0	0.0%
OFFICE OF INSPECTOR GENERAL Carryover	\$3,915 0	\$4,380 0	\$4,380 82	\$4,490 0	\$110 -82	2.5% -100.0%
Total	\$3,915	\$4,380	\$4,462	\$4,490	\$28	0.6%
Subtotal, NATIONAL SCIENCE FOUNDATION <sup>4</sup>	\$2,987,214	\$3,200,000	\$3,263,653	\$3,360,000	\$96,347	3.0%
Carryover <sup>3</sup>	0	0	11,279	0	(11,279)	-100.0%
TOTAL, NATIONAL SCIENCE FOUNDATION	\$2,987,214	\$3,200,000	\$3,274,932	\$3,360,000	\$85,068	2.6%

<sup>1</sup> FY 1994 Actual for U.S. Antarctic Logistical Support Activities of \$64.1 million includes \$62.6 million appropriated for FY 1994, plus \$1.5 million deobligated in FY 1993 and reobligated in FY 1994.

<sup>2</sup> For comparability, the FY 1994 amount for construction projects in the Major Research Equipment (MRE) appropriation, which was funded through the Research and Related Activities Appropriation, is shown in the MRE account.

<sup>3</sup> FY 1994 Actual for Carryover excludes \$35 million rescinded for LIGO.

<sup>4</sup> \$35 million available for LIGO in FY 1994 within RARA was rescinded and restored in the FY 1995 Current Plan within MRE. Total new budget authority for NSF in FY 1995 is \$3,228 billion.

### About the National Science Foundation

NSF is an independent federal agency created by the National Science Foundation Act of 1950 (P.L. 81-507). Its aim is to promote and advance scientific progress in the United States. The idea of such a foundation was an outgrowth of the important contributions made by science and technology during World War II. From those first days, NSF has had a unique place in the Federal government: it is responsible for the overall health of science and engineering across all disciplines. In contrast, other federal agencies support research focused on specific missions, such as health or defense. The Foundation is also committed to ensuring the Nation's supply of scientists, engineers, and science educators.

NSF funds research and education in science and engineering. It does this through grants and contracts to more than 2,000 colleges, universities, and other research institutions in all parts of the United States. The Foundation accounts for about 25 percent of Federal support to academic institutions for basic research.

NSF receives approximately 30,000 new proposals each year and processes a total of 60,000 proposal actions for research, graduate and postdoctoral fellowships, and math/science/engineering education projects; it makes approximately 20,000 awards. These typically go to universities, colleges, academic consortia, nonprofit institutions, and small businesses. The agency operates no laboratories itself but does support National Research Centers, certain oceanographic vessels, and Antarctic research stations. The Foundation also supports cooperative research between universities and industry and U.S. participation in international scientific efforts.

The Foundation is led by a presidentially appointed director and a National Science Board composed of 24 outstanding scientists, engineers, and educators from universities, colleges, industries, and other organizations involved in research and education.

NSF is structured much like a university, with grants-making divisions for the various disciplines and fields of science and engineering and science education. NSF also uses a formal management process to coordinate research in strategic areas that cross traditional disciplinary boundaries. The Foundation is helped by advisors from the scientific community and from industry who serve on formal committees or as ad hoc reviewers of proposals. This advisory system, which focuses on both program direction and specific proposals, involves more than 59,000 scientists and engineers a year. NSF staff members who are experts in a certain field or area make award recommendations; applicants get anonymous verbatim copies of peer reviews.

Awardees are wholly responsible for doing their research and preparing the results for publication; the Foundation does not assume responsibility for such findings or their interpretation.

NSF welcomes proposals on behalf of all qualified scientists and engineers and strongly encourages women, minorities, and people with disabilities to compete fully in its programs. In accordance with federal statutes and regulations and NSF policies, no person on grounds of race, color, age, sex, national origin, or disability shall be excluded from participation in, be denied the benefits of, or be subject to discrimination under any program or activity receiving financial assistance from NSF.

# NSF IN A CHANGING WORLD

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*The National Science Foundation's Strategic Plan*



**RESOLUTION APPROVED BY THE NATIONAL SCIENCE BOARD  
AT ITS 324TH MEETING, ON OCTOBER 14, 1994**

**National Science Foundation's Strategic Plan**

WHEREAS, Presidential and Congressional directives call for the National Science Foundation to prepare a strategic plan that incorporates a vision of the Foundation's future and the goals and strategies designed to realize that vision;

WHEREAS, with the guidance of the National Science Board, the Foundation's Director and staff have developed such a plan;

WHEREAS, the vision, goals and strategies set forth in the plan would better enable the Foundation to exercise its leadership and stewardship for scientific and engineering research and education, thus accomplishing Presidential and Congressional goals for investment of public funds;

Now therefore be it

RESOLVED, that the National Science Board approves the proposed plan entitled "NSF in a Changing World," as agreed upon by the NSF Task Force on Strategic Planning and Policy at its meeting of October 13, 1994

AND requests the Director to make such editorial changes as may be necessary, to publicize the plan widely, and to distribute it to all parts of the Nation's research and education community.

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## Executive Summary

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Since its inception in 1950, the National Science Foundation has served the Nation by investing in research and education in all aspects of science, mathematics, and engineering. As the recent report, *Science in the National Interest*<sup>\*</sup>, stressed, "America's future demands investment in our people, institutions, and ideas. Science is an essential part of this investment, an endless and sustainable resource with extraordinary dividends."

Over the years NSF's investments in research and education have helped the Nation achieve an unmatched capability in scientific and technical fields — a capability that has taken on increasing importance as we approach the 21st century.

Today, NSF's role as a leader and steward of the Nation's science and engineering enterprise faces new tests — promoting new approaches to research, education, and workforce training that reach all Americans; responding to the increased importance of science and engineering in many aspects of daily life; modernizing the Nation's research infrastructure, and adapting to a constrained budget environment.

This plan underscores the advantages that result from advances in understanding, and it emphasizes the principles that have guided the Foundation from its beginning — excellence, openness, stewardship, and impact on society. It provides a framework for moving forward in a changing environment that is grounded in the enduring values that guide NSF's mission, and it encourages flexibility in the methods used to promote the progress of science and its benefits to society.

The NSF mission, as established by Congress, is to promote the progress of science and engineering. In today's environment, fulfilling this mission requires that NSF continue to advance the discovery of new knowledge and exercise greater leadership in mathematics, science, and engineering education while taking steps to promote the dissemination, integration, and application of new knowledge.

The purpose of this plan is to delineate NSF's unique contributions to science and engineering research and education and to the Federal research portfolio. The plan provides a context for shaping NSF's future by noting how recent domestic and global changes have affected our national research and education priorities. Within this context, the plan sets forth NSF's mission, its vision, and the following long-range goals:

*Enable the U.S. to uphold a position of world leadership in all aspects of science, mathematics and engineering. This goal grows from the conviction that a position of world leadership in science, mathematics, and engineering provides the Nation with the broadest range of options in determining the course of our economic future and our national security.*

<sup>\*</sup> *Science in the National Interest*, Executive Office of the President, Office of Science and Technology Policy, August 1994.

*Promote the discovery, integration, dissemination, and employment of new knowledge in service to society. This goal emphasizes the connection between world leadership in science and engineering on the one hand, and contributions in the national interest on the other. It provides the impetus for setting fundamental research priorities in areas that reflect national concerns.*

*Achieve excellence in U.S. science, mathematics, engineering, and technology education at all levels. This goal is worthy in its own right, and also recognizes that the first two goals can be met only by providing educational excellence. It requires attention to needs at every level of schooling and access to science, mathematics, engineering, and technology educational opportunities for every member of society.*

*To move toward the achievement of these goals, the strategic plan contains a set of core strategies that NSF will employ. These strategies reaffirm the Foundation's traditions, especially its reliance on merit review of investigator-initiated proposals, yet at the same time point to new directions for the Foundation:*

*Develop intellectual capital. Seek out and support excellent activities among groups and regions that traditionally have not participated as full stakeholders in science, mathematics, and engineering, including women, minorities, and individuals with disabilities.*

*Strengthen the physical infrastructure. Modernize existing facilities and endowments and plan for future needs, including taking full advantage of the capabilities of emerging information technologies.*

*Integrate research and education. Infuse education with the joy of discovery and an awareness of its connections to exploration through directed inquiry, careful observation, and analytic thinking for students at all levels.*

*Promote partnerships. Continue to collaborate with the academic community, including elementary and secondary schools, other federal agencies, state and local governments, and comparable organizations worldwide. NSF's approach to partnership emphasizes shared interests, shared risks, and shared benefits.*

*This strategic plan is an invitation to all members of the scientific community to respond to a rapidly changing world. It is a challenge to all to pursue innovative strategies for science, mathematics, and engineering education and to develop a greater sense of leadership in science, technology, and innovation for the government and the public. Only by recognizing a truly partnership approach can we fulfill the promises of science and more fully realize the potential of our nation.*





The High Performance Computing and Communications Program seeks to speed the pace of innovation through advanced computer and networking technologies.

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## Leadership in a Time of Change and Opportunity

Throughout its history, the National Science Foundation has fostered and strengthened America's capacity to excel in science, mathematics, and engineering. NSF has done this by promoting the pursuit of excellence in research and education in all fields of science and engineering, and by providing leadership and stewardship for institutions engaged in learning and discovery.

Today, the importance of NSF as a critical investment in the Nation's future is increasingly evident. As America looks beyond a world view shaped by the Cold War, countless other challenges move to the forefront — securing long-term economic growth, protecting the quality of the environment, raising the scientific and technical skills of the workforce, building an information infrastructure, rebuilding the physical infrastructure, and generally improving the quality of life for all people. All of these challenges test the Nation's science and engineering capabilities, and meeting them requires sustained investments in fundamental research and education. The recent report on science policy issued by President Clinton and Vice President Gore — *Science In the National Interest* — underscores this very point. The report opens by saying, "America's future demands investment in our people, institutions, and ideas. Science is an essential part of this investment, an

endless and sustainable resource with extraordinary dividends."

In providing leadership for research and education activities, NSF takes advantage of its unique position in the government's portfolio of R&D programs. NSF's budget accounts for only four percent of Federal research and development spending. Its investments must be catalytic, if they are to be influential. NSF focuses on academic institutions, supporting over twenty-five percent of the basic research they conduct. This focus has led to a long-standing, synergistic partnership between NSF and the academic enterprise, one that provides the Nation with a continuous supply of both new knowledge and future generations of scientists, engineers, educators, and other technically-trained professionals. The partners share both the opportunities and responsibilities of recognizing

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the Nation's science

and engineering

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ing and responding to the challenges of the present and the future, be they readying the industrial base for competition in the global marketplace, updating school math and science curricula to meet the needs of all students, or observing and studying a rare, awe-inspiring event like this summer's collision between Comet Shoemaker/Levy 9 and the planet Jupiter.

## Fostering Linkages

Because NSF is charged with promoting the progress of science and engineering generally (rather than focusing on a specific mission in one area of science and technology), the agency's programs reach all disciplines and all levels of education and human resource development. This breadth of coverage gives the agency both the ability and the responsibility to foster the different types of linkages, synergies, and connections that are essential to effective investments for the Nation in science, mathematics and engineering. Supporting interdisciplinary research, fostering partnership with other agencies and institutions, integrating research and education, providing leadership in strategic areas of research and education, promoting international cooperation, and promulgating the highest standards of quality and excellence in all aspects of research and education are critical to the agency's future success. Its ability to contribute to the Nation depends on the leadership it provides for these types of activities.

## New Dimensions of Leadership

Today, America holds the preeminent position in what is truly a global science and engineering enterprise. Our research universities are a magnet for students and scholars from all nations, and other nations are beginning to adopt NSF's approaches to support for investigator-initiated, merit-reviewed research and education. Yet neither the Nation nor the Foundation can rest on past achievements. Indeed, NSF's role as a leader and a steward of the research and education enterprise has recently taken on a number of important new dimensions that severely test the agency's capacity for leadership and stewardship in a time of change.

First and foremost, even though science and technology remain priority areas for Federal investments, the overwhelming need to reduce the Federal budget deficit makes clear that NSF must set rigorous priorities based on realistic budgetary expectations, develop effective mechanisms for evaluation and assessment, and promote partnerships with other agencies and institutions. NSF must develop the mechanisms to determine where activities must be started, sustained, or phased down and the strength to act on these determinations.

Second, NSF's longest-standing partners — the Nation's colleges and universities — are facing an era of reduced growth in resources and major changes in the demographics of their enrollments. These shifts and their impact on the continued health and vitality of the academic enterprise will lead to modifications in the character of its partnership with NSF. This evolution deserves careful consideration in NSF's planning.

Third, the emerging challenges and opportunities of an evolving American workforce require that NSF devote increased attention to addressing the scientific and technological skills necessary for the workplace and to ensuring that all members of our society have a real opportunity to succeed in attaining them.

Fourth and finally, numerous other changes — such as restructurings of industrial research, efforts by states

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to understand and coordinate their science and technology bases, the increasingly global nature of research, new appreciation for the interdependence of basic research and its potential uses, and the growing importance of science and technology in daily life — impel the Foundation to reexamine how it structures its programs, develops priorities, and communicates the importance of the activities it supports.

The purpose of this strategic plan is to strengthen NSF's position to address and respond to these and other changes and challenges that are reshaping society's rationale for investments in science, mathematics, and engineering. In its development, NSF has drawn upon the same wealth of ideas emerging from the science and engineering community that shaped *Science in the National Interest*. The plan contains many of the same themes and describes the Foundation's view of its role in fulfilling the Administration's objectives for investments in research and education.

## Reaffirming Core Values

In strengthening NSF's position, the plan reaffirms certain core values and commitments that form the cornerstone of the agency's tradition of success. NSF remains committed to supporting and promoting:

- The most creative ideas and capable researchers, selected through merit review, including peer evaluation, of investigator-initiated proposals;
- Pathbreaking research at many points on the frontiers of science, mathematics, and engineering;
- Excellence in education and in the development of human resources in science, mathematics, and engineering — building upon the natural linkages between education and research;
- The effective discovery, dissemination, integration, and application of new knowledge through cooperation with industry, other Federal agencies, states, and public and private organizations concerned with science and technology; and
- A partnership of trust built with America's scientists, mathematicians, and engineers that serves the best interests of the American people.

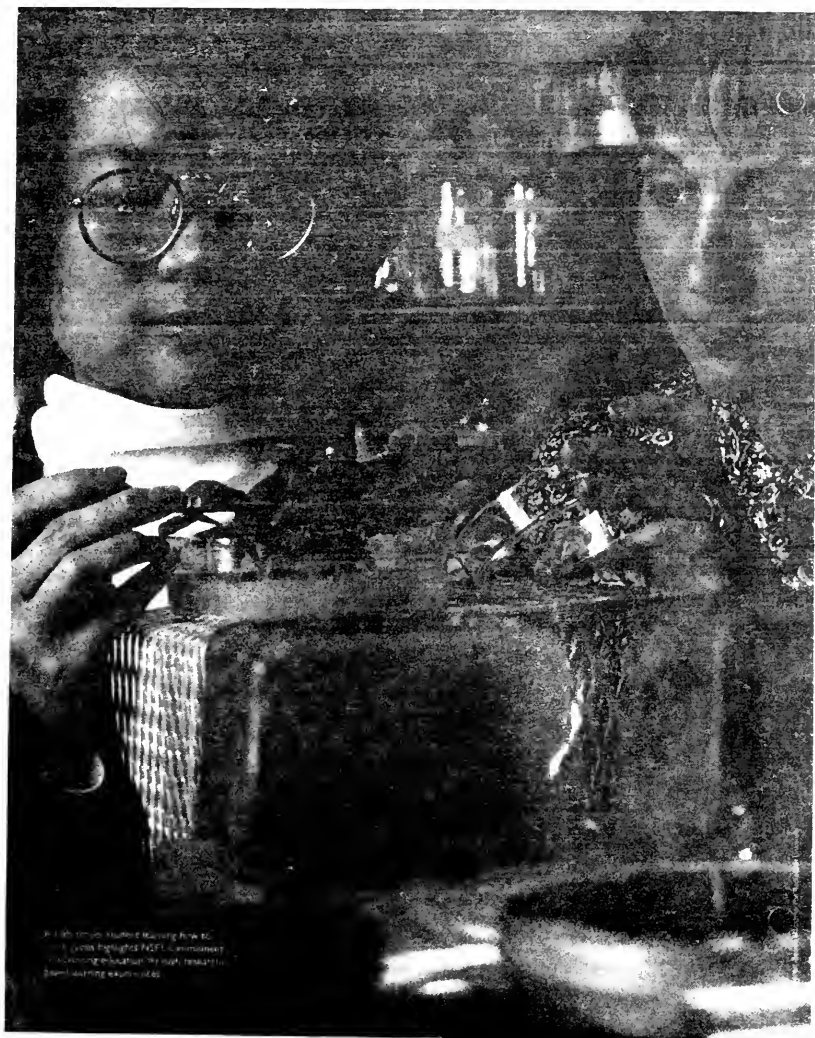
These core values and commitments establish a strong foundation for NSF — one that is rooted in the agency's tradition of success yet also provides the underpinnings for its future leadership.

In summary, this plan provides a starting point and directional guide for choosing among the many possible future paths that lie



Advanced materials research provides new insight into the structure of matter.

before NSF. It begins with three essential points of reference for the Foundation: a bold vision for the agency's future, a contemporary interpretation of its statutory mission, and a new formulation of its goals.



At 140,000, the student is making a big difference.  
The student is making a big difference.  
The student is making a big difference.  
The student is making a big difference.

## The NSF Vision

*As for the future,  
your task is not to foresee it,  
but to enable it.*

— Antoine de Saint-Exupéry

The National Science Foundation is a catalyst for progress through investment in science, mathematics, and engineering. Guided by its longstanding commitment to the highest standards of excellence in the support of discovery and learning, NSF pledges to provide the stewardship necessary to sustain and strengthen the Nation's science, mathematics, and engineering capabilities and to promote the use of those capabilities in service to society.

NSF is confident in the power of its connections and partnerships to deliver the greatest return on this investment. It will exercise leadership in strengthening

linkages among the many individuals, institutions, and organizations that are committed to progress in research and education. It will also dedicate itself to fostering the natural connections between the processes of learning and discovery.

At the core of this vision is a dynamic and diverse community of researchers, educators, and institutions who work in partnership with NSF. This community shares with NSF a commitment to discovery and learning, to enhancing the Nation's capacity for excellence in research and education, and to the use of science, mathematics, and engineering for the betterment of humanity.



Surveying changes in numbers and distribution of species enables researchers to monitor changes in Earth's biodiversity.



By introducing a signal gene from *E. coli* bacteria  
into this seedling, scientists and engineers  
support the use of AGT's biotechnology in future  
bio-remediation environmental signal detection tests.

## The NSF Mission

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The National Science Foundation Act of 1950 (Public Law 81-507) set forth NSF's mission and purpose:

*To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense....*

The Act authorized and directed NSF to initiate and support:

- basic scientific research and research fundamental to the engineering process,
- programs to strengthen scientific and engineering research potential,
- science and engineering education programs at all levels and in all the various fields of science and engineering,
- programs that provide a source of information for policy formulation,
- and other activities to promote these ends.

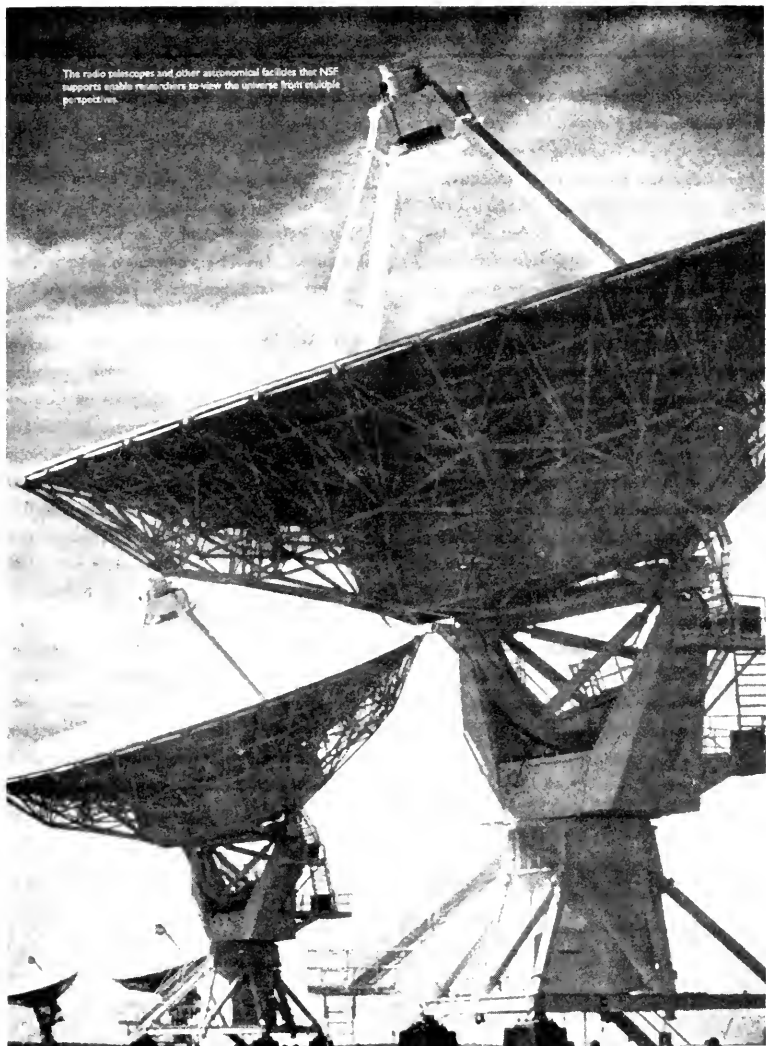
Over the years, NSF's statutory authority has been modified in a number of significant ways. In 1968,

authority to support applied research was added to the Organic Act. In 1980, The Science and Engineering Equal Opportunities Act gave NSF standing authority to support activities to improve the participation of women and minorities in science and engineering. Another major change occurred in 1986, when engineering was accorded equal status with science in the Organic Act.

NSF has always dedicated itself to providing the leadership and vision needed to keep the words and ideas embedded in its mission statement fresh and up-to-date. Even in today's rapidly changing environment, NSF's core purpose resonates clearly in everything it does: promoting achievement and progress in science and engineering and enhancing the potential for research and education to contribute to the Nation. While NSF's vision of the future and the mechanisms it uses to carry out its charges have evolved significantly over the last four decades, its ultimate mission remains the same.



The radio telescopes and other astronomical facilities that NSF supports enable researchers to view the universe from unique perspectives.



## NSF's Goals...Setting a True Course

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This strategic plan establishes three broad, closely interrelated goals for NSF that show the way to realizing the agency's vision and fulfilling its statutory mission. These goals both reflect and reach beyond NSF's traditions — with the intent of placing the Foundation in a pivotal position to help secure the Nation's scientific and technological future:

*Enable the United States to uphold a position of world leadership in all aspects of science, mathematics, and engineering.*

*Promote the discovery, integration, dissemination, and employment of new knowledge in service to society.*

*Achieve excellence in U.S. science, mathematics, engineering, and technology education at all levels.*

The first goal listed above is truly an overarching goal for the Foundation. It is a direct extension of the Administration's goal of "World Leadership in Basic Science, Mathematics, and Engineering." World leadership in all aspects of science, mathematics and engineering requires that the second and third goals be attained. Those latter goals are components of the first that are particularly timely. Likewise, world class efforts across a broad spectrum of science, mathematics and engineering support the attainment of the second and third goals. Their achievement depends on an

ample infrastructure of talent, ideas, and physical and financial resources.

### Upholding World Leadership

NSF sees its role as enabling the U.S. to uphold a position of world leadership in research and education. It will work to fulfill this goal by providing the U.S.

World class efforts  
across a broad  
spectrum of science,  
mathematics and  
engineering support  
the attainment of  
NSF's goals.

with a world-leading capability in all aspects of science and engineering — inquiry and discovery, dissemination, integration, and application of knowledge, education and training, facilities and instrumentation. This entails taking advantage of NSF's many unique strengths — especially its commitment to excellence, its ability to

work in partnership with other organizations, its commitment to linking the processes of education and research, and its experience at connecting research and

education to national priorities. The agency strives to ensure that the Nation retains a strong human and physical infrastructure for science, mathematics, and engineering. This infrastructure is both a key to world leadership and a resource on which the Nation may draw for other purposes. Upholding a position of world leadership requires exercising leadership to promote international cooperation in science and engineering, and NSF pledges to make international cooperation an important element of meeting this goal.

Promoting the discovery and dissemination of new knowledge is the traditional core of NSF's activities. Integration across fields of knowledge and tying discovery to the potential uses of new knowledge have played an increasingly important role in NSF's programs in recent years. The second goal signifies the importance of combining all these elements in our programmatic activities. It also describes NSF's explicit recognition of the role of science, mathematics and engineering in service of society. NSF is committed to devoting a significant and balanced portion of its port-

folio to areas of strategic importance to the Nation. In cooperation with the Administration and the Congress, and with input from the private sector and other organizations, NSF will define and revise its role in such areas through its continuing planning process.

The third goal encapsulates NSF's threefold commitment to science and engineering education and human resource development: (1) to give every American the understanding of science, mathematics, engineering, and technology needed for full participation as an educated citizen and for personal enrichment; (2) to provide the Nation with a technologically sophisticated workforce; and (3) to provide opportunities for young people that will attract them to and prepare them for careers in science, mathematics, and engineering.



This computer-generated image of minimal surface area illustrates how advanced imaging technologies have opened new frontiers in mathematics and other disciplines.

### Catalyzing Partnerships

NSF holds no illusions that it can achieve these goals unilaterally. That is why this plan places such strong emphasis on working in partnership with other public and private organizations engaged in science, mathematics, and engineering. As the first sentence in "The NSF Vision" (p.9) states, NSF views itself as a "catalyst" — meaning it provides the tools, the programs, and the funding to help others pursue the frontiers of knowledge and advance teaching and learning. In simplest terms, NSF lives, leads, and works through its many partners in the research and education enterprise.

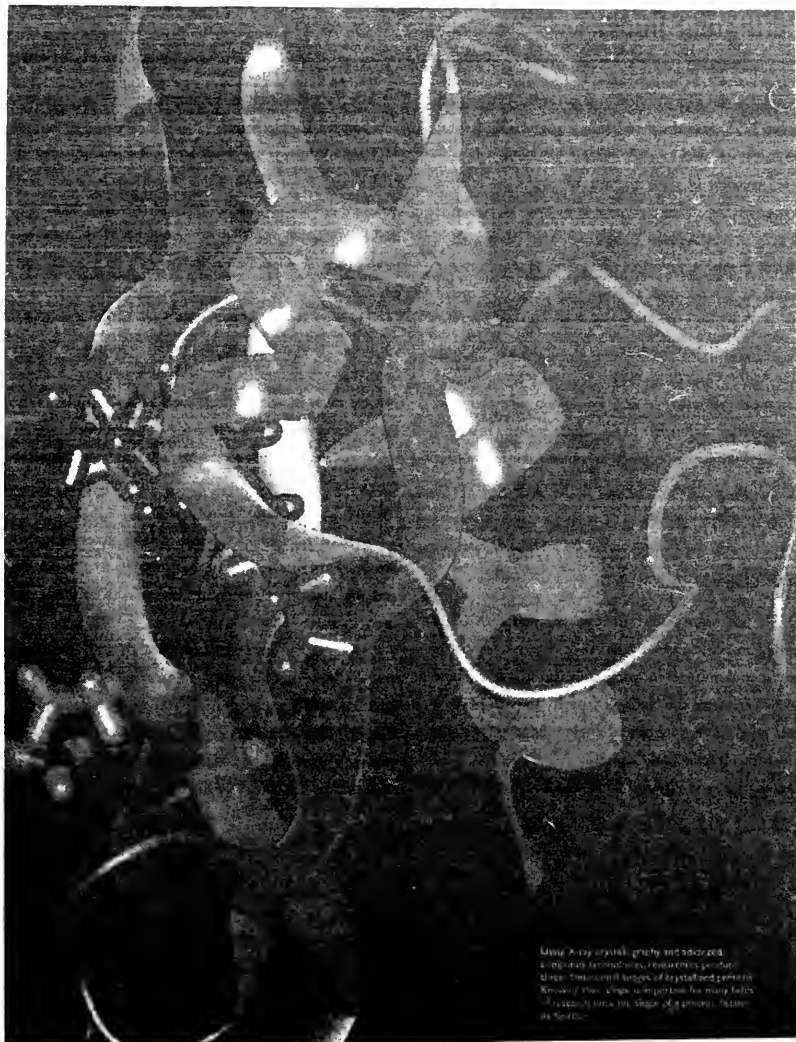
## Partners

Every citizen is a partner. The Nation as a whole—and its representatives in Congress—has a direct interest in how successful the Foundation is in fulfilling its mission because NSF supports science and engineering research and education that contribute broadly to the Nation's well being.

These benefits are diverse but nevertheless very real. Public spending on fundamental research is an investment in the future—one which is indispensable to the Nation's long-term economic well being, environmental protection, public health, and national security. NSF's programs provide educational benefits that include improved teaching of science, mathematics, and engineering. These outcomes lead to a better prepared workforce, and to a better understanding and appreciation of science and engineering by the public.

In day-to-day operations the Foundation's most direct interactions are with these partners:

- Grantees, most of them at colleges and universities, benefit directly from NSF funding. These partners include individual scientists, engineers, and educators; officials who lead the universities; and students who receive financial aid and the educational benefits of campus-based research. In addition to the direct benefits, NSF-supported research and education helps to create the next generation of educators, researchers and administrators for academia.
- Private sector business and industry benefit from ideas generated by NSF-supported research and education. A well-prepared general workforce benefiting from NSF's efforts in the schools and a technically skilled workforce of scientists and engineers are critical to the success of the U.S. economy. NSF's programs contribute to the improvement of education in schools, colleges, and universities.
- Other Federal agencies rely on fundamental research produced by NSF-funded researchers and on the availability of a workforce upgraded by NSF programs. Moreover, many of these agencies' programs are carried out in formal partnership with NSF.
- State and local officials look to NSF as a stimulus for economic development through its support for research in small businesses and industry-university partnerships.
- Schools and communities benefit directly from NSF-funded improvements in curricula, instructional strategies, teacher preparation and educational technologies which lead to systemic educational reform.
- Policy makers and researchers in all these sectors rely on NSF as a source of reliable data and analysis pertaining to science and engineering.
- Communications media inform the public about new developments in science and engineering. They rely on NSF and NSF-supported researchers for news, and they are essential in building public support for science.
- All of these diverse partners need to be considered and included when setting performance objectives and evaluating NSF programs.



Large X-ray crystal, greatly enlarged.  
 A person's face, looking up, seen  
 through a large X-ray crystal, greatly enlarged.  
 Known / This image is a portrait for many years  
 of a person's face, greatly enlarged.

## Meeting Our Goals

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To exert the catalytic leadership necessary to meet its goals, NSF must draw on its particular strengths and responsibilities within the Federal portfolio of programs investing in research and education in science and engineering. NSF's relative strengths — a prominent role in the support of research and education at academic institutions and an obligation to attend to the progress of science and engineering in a very broad sense — must be central elements in determining the core strategies that will address NSF's three overlapping goals. At the same time, NSF's mission responsibilities — support of research and education projects and strengthening scientific and engineering research potential — must be properly balanced for effectiveness in achieving its vision and accomplishing its mission in the current environment.

### Core Strategies

NSF has identified four core strategies that are designed to build a strong resource base on which its research and education programs can draw. These strategies enhance the Nation's capacity to perform as it makes progress in science and engineering:

- Develop Intellectual Capital.
- Strengthen the Physical Infrastructure.

- Integrate Research and Education.
- Promote Partnerships.

Each of these strategies is embodied in some way in NSF's programmatic portfolio. Highlighting them and developing new approaches to implementing them will make an important difference in what NSF contributes to the Federal portfolio of investments in research and education.

The first two core strategies have to do with basic components of infrastructure, the foundation on which everything else stands. For NSF to reach its goals, the Nation must have a healthy, world class infrastructure for research and education that comprises both human resources (researchers, educators, students) and physical resources (facilities, equipment, instruments) at its research and education institutions.

*Develop Intellectual Capital.* NSF's investments in the Nation's intellectual capital, that is, in the people and the ideas they create, are essential to meeting the agency's three goals.

Selecting the best ideas in research and education and the most capable people to carry them out is at the heart of NSF's programmatic activities and the merit review system with which we implement those programs. This approach and the philosophy underlying it are part of the core values of the organization. The

approach is only effective when the pool of ideas and talent on which the process draws is far-reaching.

NSF works to ensure that this pool is as extensive and diverse as possible by seeking out and supporting excellent activities that involve groups and regions that traditionally have not participated fully in science, mathematics, and engineering. This includes, in particular, women, minorities and individuals with disabilities. In a democratic society that is highly dependent on science, mathematics and engineering for its well-being and its place in the world, the scientific enterprise cannot thrive unless it is open to all segments of the population. Diversifying the workforce to create a more inclusive and robust scientific enterprise is necessary to assure excellence. Bringing the benefits of a diverse population to science, mathematics and engineering requires that NSF work with its partners toward the assignment and acceptance of responsibility for assuring that the full range of talents in the population is engaged.

America's future depends on the next generation, those currently being educated in our schools, colleges, and universities or embarking on their careers in industry, academia, or government. Enhancing their capacity to perform — create, innovate, and solve problems — and to demonstrate that capacity must be a vital component of NSF's activities. Vibrant educational programs for all students, resources to pursue advanced education and training, and resources to initiate research and education programs are important components of this enhancement.

Acknowledging excellence when it is fully apparent is comparatively easy; recognizing potential, and developing the capacity for excellence is a much more diffi-

cult task. NSF is committed to making this task an integral part of upholding world leadership.

*Strengthen the Physical Infrastructure.* In many situations in science and engineering, creative, innovative ideas go unexplored because the physical resources necessary for their pursuit are not available.

To strengthen the physical component of the science and engineering infrastructure, NSF's programs support investments in facilities planning and modernization, instrument acquisition, instrument design and development, and shared-use research platforms. In all of these areas, NSF is promoting the development of an intelligent, agile, and adaptable infrastructure for the future — one that takes full advantage of the capabilities of the emerging information infrastructure.

The physical infrastructure is an enabling aspect of NSF's activities. It helps create an environment in which effective progress is possible. The Foundation also is working with the National Science and Technology Council to develop a mechanism for inter-agency coordination of infrastructure support.

*Integrate Research and Education.* NSF's close involvement with academic institutions gives it the ability to promote the closer coupling of research and education, an ability the Foundation is only beginning to use effectively. Support for basic research in an education-rich environment characterizes the American research endeavor and distinguishes it from that in many other countries. Effective integration of research and education means that both the findings and methods of research can be quickly and effectively communicated in a broader context and to an expanded audience. This enhances the impact of the research and strengthens the infrastructure of science and technology.

In a democratic society that is highly dependent on science,  
mathematics and engineering, the scientific enterprise cannot thrive  
unless it is open to all segments of the population.

Education in a research-rich environment permits informed decisions on what can and should be taught and emphasizes for students the importance of generating new ideas and approaches, preparing them to do the same in their future careers. It also serves to produce the next generation of research-trained college and university faculty and a teaching corps that understands the real nature of science, a regeneration process that keeps the entire system vital.



Molecular models have applications in many areas — including pharmaceuticals, advanced materials, and education.

Courtesy: Science Museum, April 1987

Most research NSF supports takes place at academic institutions where the opportunity for educational interaction is abundant. Advanced training in science and engineering generally includes a research apprenticeship component, where students learn about research by doing it. Yet NSF recognizes that most education takes place outside of a research environment, and that there are stresses in the system that make it difficult to take advantage of the natural connections between research and education, even in our research universities.

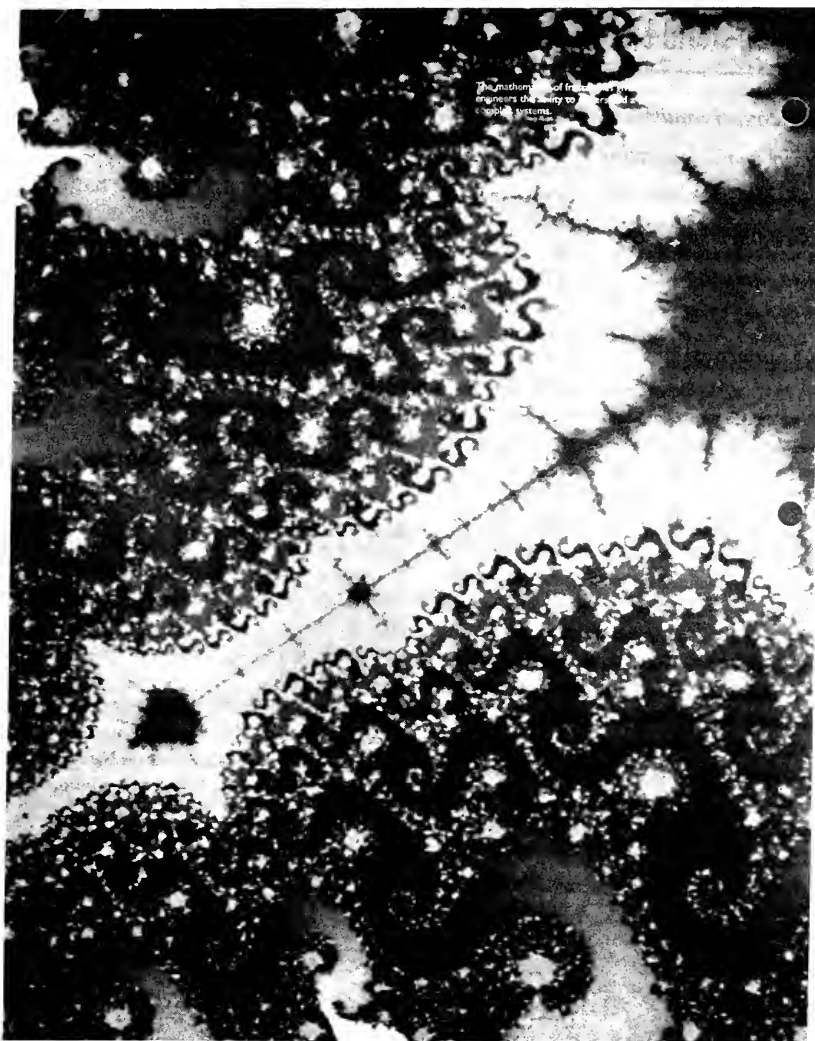
NSF aims to engage researchers and educators in a joint effort to infuse education with the joy of discovery and to bring an awareness of the needs of the learning process to research, creating a rich environment for both. We will foster these natural connections through programmatic activity that brings out the synergy

between research and education and that provides incentives for those who want to strengthen the connections. This approach emphasizes the strong bond between learning and inquiry. It recognizes the importance of building a solid understanding of math and science principles, as well as developing skills for formulating and solving substantive problems. It provides the foundation that will allow students to address effectively complex situations they have not previously encountered.

*Promote Partnerships.* This plan is based on the premise that NSF cannot reach its goals by itself. Success requires collaboration with many different partners, including the academic community, industry, elementary and secondary schools, other Federal agencies, state and local governments, and other institutions involved in science and engineering. Our goal of world leadership requires that we carry our partnerships across national boundaries, working with comparable organizations in other countries to promote international cooperation wherever mutually beneficial.

NSF's responsibility for activities across the spectrum of fundamental science, mathematics and engineering promotes its effective partnership in a variety of situations, particularly between the discoverers and the potential users of new knowledge. Partnerships also permit the agency to take advantage of the ties that the interdependence of basic research, applied research, and technology create among Federal agencies. Effective partnerships bring together the best minds in our society and may also help to share the fiscal responsibilities for research and education. Shared investments, shared risks, and shared benefits are key elements in NSF's approach to partnerships.





## Enabling World Leadership

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*"This country must sustain world leadership in science, mathematics, and engineering if we are to meet the challenges of today... and tomorrow."*

—President Clinton  
November 23, 1993

As this statement by the President indicates, America's leadership in science, mathematics, and engineering is essential to the Nation's future success and continuing prosperity. World leadership in science and engineering is not a luxury that should be pursued only in times of rapid economic growth. America's position of world leadership creates a valuable asset that yields countless dividends for our entire society.

*Science in the National Interest* underscores this point and recognizes that upholding world leadership is not simply a matter of preserving the status quo: "To

sustain the leadership position we now hold, we must improve the conditions, capabilities, and opportunities for well-trained scientists and engineers to pursue innovative research; to educate the next generation; and to apply science in areas of importance to the health, prosperity, and security of the country."

As the only Federal agency mandated to promote the health of science generally, NSF has a central role in upholding the Nation's position of world leadership, one of the priorities of the President's National Science and Technology Council (NSTC). This influences the agency's broad base of activities in research and education and its support for both the physical and intellectual infrastructure of science and engineering.

### Themes for Investment

Throughout this and following sections, the four core strategies described above provide a basic framework for the Foundation's activities. The Foundation has identified several key themes for its investments in research and education:

*Providing Balanced Support Across the Frontiers of Knowledge* — Through NSF's support for a broad base of research and education activities, the Nation is able to capitalize on new advances and new opportunities

wherever they may occur as well as anticipate and deal with new and unexpected challenges in a timely way. NSF constantly examines the status of science and engineering, using workshops, conferences, advisory and review committees, the National Science Board, and such groups as the National Research Council. These assessments ensure that breadth and quality are maintained and that NSF and the Nation can draw on the full range of science and engineering in advancing knowledge.

*Capitalizing on Emerging Opportunities* — To provide sufficient focus within its breadth of activities, NSF conducts assessments like those mentioned above with an eye to emerging areas of science and engineering, challenges in education and human resource development, and other areas presenting particular opportunities or challenges.

*Taking Risks* — Like all investments, research and education are inherently uncertain ventures. Outcomes are difficult to predict; even in the broader context of whole fields, unexpected results may overturn accepted theory and lead experts to think along completely new paths. NSF must find new ways to encourage its investigators to explore new avenues and pursue activities with high risk and high potential impact. Improved incentives may help overcome concerns investigators may have

about how to move in new directions without jeopardizing their resource base and therewith, their productivity.

*Integrating Across Disciplines* — Although the disciplinary structure of science and engineering is designed to reflect the underlying order of the natural world, nature in fact knows no disciplinary boundaries. While NSF has a discipline-based organizational structure to facilitate its work, it recognizes the need to ensure that its structure does not create artificial barriers to the support of science and engineering that spans more than one area. NSF will explore and establish organizational mechanisms and programmatic incentives to ensure that multi-disciplinary research and education activities receive appropriate attention.

*Establishing Beneficial International Linkages* — NSF does not view the pursuit of world leadership as a competition among nations. Research and education in science and engineering benefit immensely from international cooperation. NSF promotes the internationalization of science and engineering in two ways. It enables and encourages U.S. scientists, engineers, and their institutions to avail themselves of opportunities to enhance their research and education programs through international collaboration. NSF also provides future generations of U.S. scientists and engineers with the experience and outlook they will need to function productively in an international research and education environment through support for traveling fellowships and research activities at overseas sites.

These themes form the core of how NSF will enable the U.S. to uphold its position of world leadership in science and engineering. They are nevertheless incomplete, because the Nation's position of world leadership also depends greatly on NSF's efforts toward reaching its other two goals.



Micro-engineering, where smaller is better, is an important part of NSF's efforts in manufacturing and advanced computing.


## Discovery

In the 1930's, physicists set about characterizing the magnetic properties of the nuclei of the elements. If the nucleus had an intrinsic spin, it was found to possess a magnetic moment – that is, to behave as a tiny bar magnet. The goal of this research was to understand the structure of the nucleus. The experiments were done in atomic beams that passed through magnetic fields in which radio waves caused the magnetic moments of the nuclei to change their spatial orientation at certain "resonance" frequencies. These early studies of nuclear magnetic resonance (NMR) provided useful models about how to picture the behavior of the protons and neutrons inside the nucleus, but the complete explication of nuclear structure remains even to this day a major puzzle.

Nevertheless, the major scientific payoff of this research, which certainly was not anticipated by those who carried out these early studies, was not in nuclear physics, but instead in chemistry, where, starting in the late 1950's, NMR has displaced many other forms of chemical analysis. Today, NMR is one of the fundamental tools that chemists employ to analyze molecules in solution and to determine connectivity in compounds – that is, what atoms are nearest neighbors to what others. Countless hours have been saved because chemists can make routine use of NMR to characterize new compounds they synthesize.

But the largest payoff to society may actually be elsewhere—in the realm of medical diagnosis. By using a magnetic field whose strength changes with distance, images can be prepared of the nuclei in a material, such as a whole human body. The technique is called magnetic resonance imaging (MRI). Currently, MRI is increasingly replacing x-rays as the method of choice in visualizing bone and tissue, particularly as a diagnostic tool for recognizing cancerous growths and other tumors.

Who would have thought that wondering about the structure of the nucleus would more than 50 years later be the basis for a new medical procedure (and a new industry) that is saving lives by the early detection of disease states? This example is just one of many such that reveal the surprising interconnections of science and technology. It also illustrates why the National Science Foundation must be willing to invest for the long term in areas of science where the immediate impact on society may not be obvious.



NSF's Advanced Computing program promotes innovative applications of emerging technologies and provides valuable learning experiences for today's and tomorrow's scientists and engineers.

## In Service to Society: NSF Strategic Areas

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NSF's second goal, *Promote the discovery, integration, dissemination, and employment of new knowledge in service to society*, highlights why it is in the national interest to uphold a position of world leadership in science and engineering. At the same time, excellence in research and education that serves society is an important component of world leadership.

Among the many research and education frontiers that NSF's programs address are areas of clear strategic importance to the Nation. The Foundation invests a major portion of its resources in these strategic areas, which are organized and focused around specific national objectives identified by the President's National Science and Technology Council (NSTC) and the Foundation's own planning process. It is important to note, however, that the fundamental nature, the quality, and the educational impact of the work supported in these strategic areas does not differ from those of other activities supported by the Foundation.

Within NSF, these research areas emerge from a continuous planning process that takes into account input from many sources, such as reports, workshops, and advisory committees. In this way, NSF both influences and responds to the Administration's National policy for science and technology. NSF's process also

considers a number of other factors, such as the availability of infrastructure and resources sufficient to accomplish the objectives, the existence of emerging research opportunities resulting from new capabilities in science and engineering, and the potential to foster partnerships and attract additional resources that can accelerate and increase society's return on the investment. The specific strategic areas and their relative priorities are reviewed annually as part of the planning and budget process. They also are subject to change as the Nation's needs and priorities evolve.

NSF's programmatic activities in the strategic areas are designed in keeping with the Foundation's unique role among Federal agencies and its longstanding partnership with the academic sector. NSF's activities in the strategic areas seek to expand the knowledge base; improve education and training of future scientists, engineers, educators and citizens; stimulate knowledge transfer among academia and the public and private sectors; bring the perspective of many disciplines to bear on complex problems important to the Nation; and enhance components of the infrastructure supporting research and education, including access to the expanded knowledge base.

NSF also aims to foster the natural connections

among the strategic areas, because these interconnections are critical to success. They effectively allow the Foundation to increase the return of its investment in these areas, to reduce duplicative efforts, and to coordinate the allocation of its resources.

### NSF Activities in Strategic Areas

The following discussions are based on the coordinating plans developed for NSF's activities in each of the strategic areas. NSF's seven strategic areas are grouped under three related priority areas established by the NSTC — Improved Environmental Quality, Harnessing Information Technology, and Job Creation and Economic Growth.

#### Improved Environmental Quality

Environmental quality has a broad impact on human health, safety, and quality of life. It affects the quality and quantity of food, fiber, energy and water supplies, as well as the enjoyment of a wide range of recreational opportunities. Environmental issues are diverse, with local, regional and global components. A balanced, comprehensive, integrated and coordinated program of multi-disciplinary research and development is critical to improving environmental quality.

*Global Change* — Since 1987, NSF has participated in and provided leadership for the U.S. Global Change Research Program (US/GCRP), whose goal is to produce a predictive understanding of the Earth system to support national and international policy-making activities across a broad spectrum of global, national, and regional environmental issues. The primary global change research emphasis at NSF has been the support of activities that advance fundamental understandings of the complex interactions among different facets of the Earth system. In addition to expanding knowledge of physical, biological, and socioeconomic

processes, the NSF effort seeks to facilitate data-acquisition and data-management activities necessary for basic research on global change, and it encourages advancement of modeling activities designed to improve representations of Earth system interactions.

*Environmental Research* — The proper balance of environmental quality and sustainable development poses a major scientific and technological challenge for the twenty-first century. Present and future efforts to preserve, manage and enhance the environment require enhancing current research and education activities. NSF will provide support for interdisciplinary research across a broad front of sciences — biology, chemistry, engineering, geosciences, materials science, mathematics, and the social sciences. This is needed to help address problems whose scope is comparable in size and complexity to that of national defense. Current plans for NSF's Environmental Research effort are built upon four integrating themes: biodiversity, water and watersheds, environmental technology, and resource use and management.

#### Harnessing Information Technology

Information technology has the potential for improving the quality of life, protecting the environment, safeguarding national security, and ensuring economic growth. Government is working with industry to develop the National Information Infrastructure (NII) that the U.S. will need for the 21st century.

*High Performance Computing and Communications* — The NSF High Performance Computing and Communications Program (HPCC) supports and elaborates upon a Federal program of the same name. The Federal program seeks to extend US technological leadership in science and engineering, to speed the pace of innovation, and to accelerate wide dissemination and application of high performance computing and communications technologies. This program is organized

into five components: high performance computing systems, advanced software technology and algorithms, national research and education network, basic research and human resources, and information infrastructure technology and applications, the latter most directly linked to the NII.

### Job Creation and Economic Growth

Promoting economic growth, creating rewarding jobs, and ensuring U.S. competitiveness in world markets help raise living standards and the quality of life for all Americans. While science and technology are not sufficient to carry out these government objectives, they provide an important component of what is necessary.

*Advanced Manufacturing Technology* — Manufacturing is a highly integrative activity, and manufacturing-related problems are among the most complex interdisciplinary problems faced by modern society. NSF concentrates on developing the fundamental science and engineering knowledge base that underlies manufacturing technology, management, and education and training, as well as technology transfer, diffusion, and implementation. NSF also focuses on enhancing the institutional, physical and human resources that constitute the manufacturing research and education infrastructure.

*Biotechnology* — The scientific revolution that has vastly increased our understanding of the living world offers us expanding opportunities to use this knowledge for the welfare of the Earth and humankind. The scientific and engineering research that makes possible these practical applications, broadly termed biotechnology research, can play a critical role in our Nation's future technological strength and economic growth, in preservation and restoration of the environment and biodiversity, and in the health and quality of life of all people. NSF's biotechnology efforts are currently focused on six key research areas that are important to

the future economic development and international competitiveness of the United States: environmental biotechnology, bioprocessing, bioelectronics and bionetworks, agricultural biotechnology, marine biotechnology, and the social and economic dimensions of biotechnology.

*Advanced Materials and Processing* — The 21st century will provide unprecedented opportunity for the exploitation of new materials and new technologies. Powerful new technologies that are no longer materials-limited will provide the Nation with the knowledge and technical capabilities to be fully competitive. Improved materials and processes will play an ever increasing role in efforts to improve energy efficiency, promote environmental protection, ensure security, develop new and improved health-care systems, create an information infrastructure, and provide modern and reliable transportation and civil infrastructure systems. NSF focuses on the synthesis and processing of new and improved materials; theory, modeling and simulation of materials and processing; broad interdisciplinary training; and development and acquisition of advanced instrumentation.

*Civil Infrastructure Systems* — The vitality of the Nation's civil infrastructure affects its ability to efficiently transport people, goods, energy and information; provide clean air and water; control disease; and conduct commerce. There is an urgent need to rebuild America by emphasizing intelligent renewal of its civil infrastructure systems, a process that is cost-effective and, at the same time, assures high-level performance and longer-term life through continuous technology innovations. Intelligent renewal of infrastructure systems must begin with integrated research that will lead to new designs, more durable materials, new integrated network systems with better controls and communications, and improved decision-making and management processes.





Through education both in and out of the classroom, COS hopes to motivate young people to study science and mathematics and gain the skills needed to be full participants in the work force and our democracy.

## Excellence in Education at All Levels

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As part of its mission to promote the progress of science and engineering, NSF supports individuals and groups to undertake activities that ensure a technologically literate populace with the understanding and skills needed for the workforce of the twenty-first century as well as a well-trained cadre of scientists and engineers for the present and the future. Some of these activities take the form of projects dedicated to education and human resource development; others take place in the context of projects aimed at advancing the frontiers of knowledge or addressing strategic national goals.

In forming its investment strategy for education and human resource development, NSF's aim is to ensure that all members of society have real opportunity to succeed in science and technology so that the Nation can draw upon the strength and creativity that the diversity in our society has to offer. In particular, NSF is determined that all students at all levels will be exposed to programs with high standards for understanding and accomplishment; that all students have the opportunity to advance to higher levels; that all students who enter advanced training at the professional level are well and broadly trained; and that the process of learning does not end with the classroom.

Meeting this goal requires efforts from all parts of the Foundation. The undergraduate level plays a piv-

otal role. It is the conduit through which research can reach the Nation's schools. All NSF organizations have responsibilities at this level. Developing the appropriate blend of broad, flexible underpinnings and focused attention to disciplinary specifics is critical to meeting the full range of NSF objectives.

Four overlapping categories combine with the broad thematic emphases on integrating research and education and building diversity in the human resource base for science and engineering to address the National Science and Technology Council's priority for An Educated Citizenry systematically. They do not cover all aspects of the investment in education and human resources, but they provide a framework for describing the character of the investment.

*(1) Systemic Reform K-12* — Since the initial articulation of National Education Goals in 1989, the Federal Government has adopted a comprehensive strategy for working toward the goal centered on making the U.S. first in the world in science and mathematics achievement. Systemic reform is the strategy adopted by NSF (as well as the recently passed GOALS 2000 for the Department of Education) to bring about the changes necessary to make progress towards the goals. Systemic refers to fundamental, comprehensive and coordinated changes made in science, mathematics

and technology education through attendant changes in school policy, financing, governance, management, content and conduct. Specific efforts focus on changes at the state, city, rural areas and local school district levels. Collaboration and development of partnerships are necessary for improvement. Teacher training, curriculum adoption and adaptation, and appropriate assessment are key elements of systemic plans. The outcomes expected are improved science, mathematics and technology education for all students; preparation of a technologically competent and diverse workforce; and enhancement of scientific and technical literacy, understanding, and skills.

(2) *Workforce* — Developing and maintaining a strong corps of workers for all facets of the American economy are essential to the well-being of the Nation. NSF can play a key role by helping academic institutions to provide a quality science and mathematics education for all students at all levels. Workers well-grounded in science and mathematics are critical to occupations both in and out of the science and technology enterprise. NSF has responsibilities to improve the preparation and enhancement of teachers in the Nation's secondary and elementary schools, to help provide quality science and mathematics experiences for those choosing to enter technician/technologist fields, and to encourage and support young people to pursue careers in science, engineering, and technology at advanced levels. These responsibilities are addressed through curriculum reform, development of faculty and teachers, providing research experiences for students, and promoting learning connected to context, phenomena, and realistic use. Workforce education in science and technology will increasingly become a life-long process.

(3) *Flexibility in Advanced Training for Scientists and Engineers* — The development of advanced training for scientists and engineers has occurred largely as a component of research programs, rather than through a strategic consideration of national needs for the science and technology workforce. As a result, many see the

current system as one that tends to replicate itself by producing scientists and engineers trained for increasingly narrow - and increasingly limited - research roles. This works against the broader interests of our best students, the increasing diversity of today's generation of students, and the complex and rapidly broadening roles in our society played by those with science and engineering training. NSF aims for a flexibility in advanced training for scientists and engineers that will develop broadly educated people with the knowledge and skills necessary to address the needs of the Nation in a rapidly changing world. Encouraging undergraduate research experiences, developing curricula with broad perspectives and ensuring their dissemination, providing opportunities for students to interface with industry through internships or exchanges, and encouraging a broad view of professional possibilities and responsibilities provide NSF with an approach to developing flexibility. Some of these more broadly educated scientists and engineers will become the faculty members who will help determine the future of the academic enterprise.

(4) *Scientific and Technological Literacy* — Enhancing the scientific and technological literacy of the American people is seen as one of the keys to global competitiveness and to personal enrichment and quality of life, as well. Citizens who are scientifically and technically literate will be better able to participate in the democratic society by making informed decisions on matters involving science and technology. They will understand the need for a strong and robust science and technology enterprise, support its inclusion as a Federal funding priority, and encourage and motivate young people to study science and mathematics. Stronger efforts to disseminate the results of research are necessary to gain the understanding and support of citizens and legislators. Creative uses of museums, zoos, radio and television, libraries, and other non-academic organizations will be increasingly important in meeting this responsibility.

## NSF's Guiding Principles

The National Science Foundation is in many ways a unique Federal agency. Its relationships with the academic research community and with the science and engineering education community must be both a working, trusting partnership and an arm's length, impartial interaction. In managing the Federal research investment, NSF must simultaneously be part of the research and education community and independent of it. The following set of guiding principles allows the Foundation to maintain this delicate balance.

**STEWARDSHIP:** As responsible trustees of public funds, NSF will provide the American people with the best possible management of its investment in research and education in science and engineering:

- We work with many others who share our values and goals: colleges, universities, private industry, other governmental agencies, and scientists and engineers in other countries.
- We are committed to putting research and education in science and engineering to work for the American people, and to helping the public understand the importance of research and education for their lives.
- We rely on our proven system of merit review, which weighs each proposal's technical merit, creativity, educational impact, and its potential benefits to society.
- We promote professional integrity in our own work and in the research and education we support.
- We strive to bring research and education closer together at every level, from hands-on inquiry-based teaching in grade school to dissertation research in graduate school, and beyond.

**LEADERSHIP:** The researchers and educators supported by NSF are eager to pursue new opportunities for knowledge and educational reform wherever they occur. As the leading Federal supporter of fundamental research and education in science and engineering, it is essential to identify areas of national need as well as areas of intellectual opportunity:

- We accept the challenge of leadership and the responsibilities that go with it.
- We identify and promote research with the greatest potential, whether or not it fits traditional views.
- We promote education in all segments of society, whether or not they have been part of the scientific and engineering traditions.

**IMPACT:** NSF and the community it serves are convinced that science and engineering can improve our world, our society, and ourselves:


- We have seen that research and education in science and engineering can address fundamental needs around the world.
- We see the extraordinary benefits that scientific and technological breakthroughs have bestowed on our society.
- We are renewed by the never-ending challenges of research and discovery.
- We strive to affect the structure of institutions in positive ways.

**EXCELLENCE:** NSF and the community it serves are committed to Excellence, as a personal and an organizational standard:

- We strive to develop the potential for excellence in ourselves and others.
- We find excellence and the potential for excellence in all parts of our population, and we work hard to identify and nurture excellence wherever it may occur.
- We believe that excellence is contagious: creating pockets of excellence will lead to widespread impact.
- We place a high value on creativity; it is the fuel that drives excellence.

**OPENNESS:** NSF and the community it serves are committed to the sharing of information and a free marketplace of ideas:

- We conduct our business in an open manner, inviting advice from and evaluation by our customers.
- We disseminate information on our programs in every way possible, to promote fair and equal access to funding opportunities.
- We are vigorous supporters of computer networks that accelerate and widen the flow of information and ideas.
- We assure the open dissemination of the results of NSF-supported research; we do not support classified research.



By supporting individual investigators as well as groups and centers, NSF employs a variety of support mechanisms - helping to open new frontiers of knowledge.

## Approaches to Implementation

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To meet the challenges of the changing world, NSF will use a variety of approaches in pursuing its goals. NSF's future will see support of teams, centers, and consortia as well as individual investigators; focused proposal solicitations as well as unsolicited proposals; increased emphasis on integration of knowledge; and increasing reliance on partnerships. This section outlines a few of these approaches.

*Offer Different Modes of Support* — The needs and opportunities of the science and engineering enterprise come in all shapes and sizes. The challenge to NSF is to meet these needs and pursue these opportunities in ways that are appropriate in each case. Many NSF projects are well suited to the traditional mode of supporting an individual investigator. Some research questions and education initiatives require support for groups of specialists. Other problems will yield only to high levels of sustained support provided to research or education Centers. High risk projects sometimes need small grants for short-term exploration, while other projects require sustained periods of support in order to study long-term processes. Research sometimes requires specialized instruments or facilities, and many areas of science and engineering require dedicated research platforms that are beyond the size and scale available to individuals or small groups. NSF must provide a vari-

ety of instruments and facilities necessary for the conduct of pioneering research and education.

*Improve Agency Efficiency and Accountability* — As the steward for public investments in science and engineering research and education, NSF is committed to improving its organizational performance. Developing credible performance measures and assessment meth-

ods is a critical component of NSF planning. NSF's data collection program will enable policy makers and the general public to monitor the progress that NSF is making toward its goals. This will require continuous improvement of proposal review, grant making and other processes, including response time. Merit

**An important approach  
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Nation use new  
knowledge in science  
and engineering for the  
benefit of society.**

review with peer evaluation is the core of NSF's decision making process. NSF is committed to making this an open, fair, and robust process. Accountability for public funds will demand assessment of the effectiveness of agency operations and the return on the

Foundation's investment strategies.

*Promote Intellectual Integration* — Intellectual integration brings the knowledge and skills from different disciplines to bear on complex problems. NSF will encourage intellectual integration among fields of science and between research and education missions. Collaboration across traditional disciplinary boundaries is a positively reinforcing process: the first interdisciplinary discoveries lead to the discovery of many new problems at that disciplinary interface. Innovative research methods and tools can stimulate the imagination of researchers at disciplinary frontiers and open new paths for action. Integration of research and education activities maintains the currency of what is taught, ensuring an up-to-date research community and a technically agile workforce.

*Accelerate Knowledge Transfer* — An important approach to carrying out NSF's mission is to help the Nation use new knowledge in science and engineering for the benefit of society. The transfer of such knowledge is a vital ingredient in enhancing the Nation's industrial competitiveness. NSF's knowledge transfer activities are focused on building working



The strong, flexible buckyball molecule has potential applications in materials sciences and micro-engineering.

relationships at the research project level between academia, industry, and other potential users, such as local and State governments. Knowledge is used most rapidly

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when those charged with discovery are in close contact with those charged with applying new knowledge. This approach is particularly effective when there are one-to-one working relationships and people exchanges; for example, when university-trained researchers and professionals move to industry and vice-versa.

Reflecting changing national priorities, there has been a gradual shift so that NSF, while increasing its support for fundamental research, has also assumed a greater concern with technology and the transfer of knowledge to industry. NSF has established programs that are actively oriented toward knowledge transfer: for example, multidisciplinary centers with technology transfer as explicit components of their research mission, Small Business Innovation Research (SBIR), and Small Business Technology Transfer (STTR) programs, which help to move the results of basic exploratory research to the marketplace.



NM provides the majority of federal support for academic research in paleontology and archaeology. In this photo, a paleontologist works to uncover a well-preserved bone, rib, and skull from a mastodon estimated to be 12,000 years old.



Meteorologists use supercomputers to predict,  
plot, and study storms.



## Planning and Allocation of Resources

The goals, strategies, and approaches outlined in the previous sections provide the strategic framework within which the Foundation and its organizational units will prepare performance plans, allocate resources, and assess results. NSF's three interrelated goals and the various strategies and approaches needed to achieve them ultimately require a balanced approach.

The successful implementation of this framework is the next (and perhaps most challenging) step in this strategic planning process. Just as any investor seeks a balanced and diversified portfolio, the Foundation

strives for balance among the elements of its varied portfolio in order to maximize its overall value to the public. There is no simple formula to do this, for the ideal balance changes continually. If successfully implemented, this plan and the Foundation's planning process will provide the guidance necessary to attain a timely balance.

### Criteria for Implementation

An implementation plan to complement this strategic plan is now under development. This plan will establish criteria — such as consistency with NSF and NSTC goals, appropriateness for NSF (in the interagency context), timeliness of proposed activities and readiness of the community to carry them out with requisite quality, and the potential for partnerships — to set priorities for NSF activities.



Polar research uncovers history locked in snow.

## Acknowledgments

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Dr. Anne C. Petersen, Deputy Director

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The Director's Policy Group, the senior management of the Foundation, consists of the Foundation's Assistant Directors and Office Heads.

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The National Science Board is the policy making body of the National Science Foundation, with the added responsibility to recommend and encourage the pursuit of national policies for the promotion of research and education in the sciences and engineering.

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Mr. WAMP. Speaking of yielding to wisdom, I'd be remiss if I didn't recognize the attendance of our Full Committee Chairman, the gentleman from Pennsylvania, the Honorable Bob Walker, very capable leader of the Full Science Committee, self-described technonut.

Mr. Chairman, if you would like to make a comment at this time, the Chair will recognize our Full Committee Chairman.

Mr. WALKER. Thank you very much, Mr. Wamp. I'm delighted to see you in the Chairman's chair. It's a nice place to see rising freshmen moving.

I am delighted to be with you today, at least for a short period of time, and welcome Dr. Lane here.

I think both in this Subcommittee and in the Full Committee, the National Science Foundation will find many members on the majority side and, for that matter, on the minority, who are devoted to the mission of basic research that the National Science Foundation so capably carries out on behalf of the country.

These are going to be very tough, lean times in terms of trying to find a way to a balanced budget by the year 2002. And this Committee will maintain its commitment to helping be a part of that effort.

But we do intend, as a part of our work, to maintain the basic research and the basic science mission of this country. And we are going to be looking to you to help us sort through the issues before the National Science Foundation and in fact before the nation to assure that we do these things in the right way.

And so we're delighted to have your testimony. We thank you for coming here and answering questions from our members. We think that this kind of hearing will give us a better roadmap as to where to proceed in the weeks and months ahead.

Thank you, Mr. Chairman.

Mr. WAMP. Thank you, Mr. Chairman.

I second the comments of our Full Committee Chairman, and remind everyone of the commitment that President Ronald Reagan had to the National Science Foundation. Many of us, the new members of the 104th Congress, are Reagan republicans and the long-term investment, the legitimate role of federal government backing basic research and long-term strategic science planning clearly believe, as our Chairman does.

And you've answered my first question, Dr. Lane, but I would open with a question, keeping those budget sensitive matters on the table here for a few minutes, and recognizing that some of your budget proposals are big ticket items, we know it's going to, these pressures are going to force us all to take a hard look at all of our activities.

And within the National Science Foundation portfolio, we have several big ticket items on the horizon.

The LIGO project, the \$300 million gravitational wave observatory, which you spoke about earlier coming up, or other potential projects as the Polar Cap Observatory, estimated at \$25 to \$30 million, a new Arctic research vessel which could go for something like \$150 million, a new radio telescope \$200 million range, reconstruction of the South Pole Station \$200 million range.

Last year, the Foundation established a new major research equipment account to budget and manage the construction of large-scale highly specialized national research facilities. Last year, the Congress provided support for the gravitational wave observatory and the Gemini telescopes through this mechanism.

First, if you will, please describe for the Subcommittee the National Science Foundation process for sorting through all these potential major national research facilities. How do you determine which ones are candidates for the new major research equipment account, and how will you make tradeoffs and decide between these kinds of projects, assuming you have sufficient resources.

What kind of procedures and process have you put in place for projects to be funded through the major research equipment account.

And then tell us how your planning process is dealing with these items in the face of the budget reductions the Administration is planning for the Foundation over the next five years.

And call on any of your under secretaries, if you would, yes, all in five minutes,—

[Laughter.]

Mr. WAMP. Excuse me.

Call on any of your assistants or under secretaries, Dr. Lane, just by identifying them if you would when you call them to the microphone.

Dr. LANE. Thank you, Mr. Chairman.

Let me start with this, and then I'd like to ask my partner here, Anne Petersen, to comment.

The first thing I would like to emphasize is that these projects, the ones that NSF has done and carried out in the past, and those that are currently under construction and those that are being considered in the future, are really science projects that arise out of the science community.

They are facilities, major pieces of instrumentation, telescopes, accelerators, other large experimental devices or computational devices, that are needed in order to advance science in one or another of the areas that NSF supports.

So there's always much discussion in the community, often National Academy of Science studies, and other reports and studies, before the NSF seriously puts one of these on the table.

Once NSF takes serious interest in such projects, there's a considerable amount of internal review and study. The first phase is really a conceptual proposal for the project in which the goals are identified and the sort of best estimate without doing detailed cost analysis of the cost of the project, early discussion of the importance of such a facility to the science goes on inside the NSF, including discussion with the National Science Board.

But before any serious approvals are requested inside the NSF, the next step then is a program planning, a project approval where the request is made to spend money required to actually put together a detailed plan that will provide information on the detailed cost of such facility, the way in which it'll be operated, what the user communities will be, how it will be managed and so on, and that also involves considerable discussion with the Board.

And a couple of projects have recently had that kind of a discussion with the Board. The millimeter array and new astronomical observatory project, and also South Pole Station.

The LIGO project of course some time ago went through those phases and a considerable amount of R&D money has been invested in that project, and a very thorough, comprehensive review carried out this last year, analyzing the costs in detail, and after considerable discussion by the National Science Board, the National Science Board approved a total project cost and authorized the go-ahead on that facility.

The major research equipment account that you referred to, Mr. Chairman, is a relatively new account. I guess we're in the second year of having that line in our budget.

And it is a mechanism to make explicit a very large construction project such as LIGO. And in 1996, LIGO is the only project that is in that account.

The Gemini projects were there in '95. They're fully paid now and that's the reason they don't appear in 1996.

That account is, we feel, very important to our ability to focus on the funding and the progress of these large, high visibility projects, and LIGO certainly qualifies as the largest of those at this point in time.

We have developed a whole series of procedures inside the Foundation that must be followed in order to have a facility accepted in the major research equipment account and the final stage of that long set of procedures is the approval by the National Science Board.

We of course are using those procedures with new facilities that are being proposed at the present time.

The issue of budget, of course, we take very seriously. Depending on our budgets over the next five years or so, we will be able to do more or less investment in research facilities.

We can't simply stop providing the experimental facilities needed in these various fields but it's an important issue of balance as to how much we invest and at what rate we're able to construct such large facilities. That's the discussion we're having at the present time with the Board.

I'd like to ask Dr. Petersen if she'd like to add any comments.

And then if there are any questions about any of the specific projects you mentioned, I would call on the assistant directors.

Mr. WAMP. Dr. Petersen?

Dr. PETERSEN. Thank you.

That was a very good summary, I think, by Dr. Lane.

Let me just quickly mention some of the features that we scrutinize within the Foundation.

We require that there be evidence that the fields who would use this equipment really are supportive of it, so we need evidence from the potential consumers that this really is a high priority in that field.

Projects also need to be consistent with our strategic plan. And then they need to have a systematic set of proposals that identify the overall science and engineering merit.

We have to have a technical and engineering feasibility study. We examine interagency and international collaboration, and this

may in fact become increasingly important with many of these projects.

And we also require cost-sharing by the disciplines that would be involved with this particular project.

We've also begun to look at projects themselves competitively, recognizing that there's a finite amount of money and that we really must have clear priorities and make investments where they are most needed relative to one another.

Thank you.

Mr. WAMP. Thank you, Dr. Petersen.

The Chair recognizes again the Ranking Member from Texas, Mr. Geren.

Mr. GEREN. Thank you, Mr. Chairman.

Dr. Lane, NSF's current priority is to support research projects over research infrastructure.

At what point does the prioritization break down? That is, will the policy not lead to a situation in which academic scientists tailor their proposed research projects to the capabilities of an antiquated research facility, rather than propose research projects at the cutting edge of the research fields?

Are you satisfied with \$100 million proposed in the FY '96 budget, four percent of NSF's total research budget, is it the appropriate amount for facilities for an agency that supports 25 percent of all academic research?

Dr. LANE. Well, Mr. Geren, the need really is there. I think that's clear, as you pointed out from the reports that have been done, studies that have been done, including those by the National Science Foundation, the various estimates of the overall need. But it's numbers approaching \$10 billion in the views of many people who look at that.

NSF's position has always been that given its size, it really cannot hope to take on that whole, dealing with that whole problem as one agency, and we've always supported the idea of a multi-agency, a federal program, to jointly, with institutions, support the renovation and modernization of these important laboratory facilities.

And we still hold that view. We are participating and have taken some leadership in the study underway under the President's National Science and Technology Council, a study on multi-agency approach to academic research infrastructure, and that report is in late draft stage right now.

The committee is chaired by Dr. Nat Pitts, who is the director of our research infrastructure office at the NSF. We're very supportive of that process, and NSF certainly expects to continue to play a role in supporting modernization of facilities and the purchase and development of advanced experimental instruments.

Given the funds available to us in the 1996 budget, our feeling was that if we were to go to the full \$250 million, it would in fact cause substantial reductions in grants for research and education activities.

We simply felt, given the sort of high cut off level of funding, the fact that we really are unable to fund so many proposals that rate very highly, that that should be our priority in the '96 budget.

We're pleased that we are requesting the largest amount of money for research infrastructure in this budget that we have ever requested, double what we have requested in the previous year.

Mr. GEREN. Do you feel that, you talk about the interdisciplinary approach to try to address this problem, do you feel like that's happening?

A concern that I have is that where that might be certainly a goal that we ought to seek if it's not in fact coming about, is it going to compromise what you're trying to do as the NSF, if this interdisciplinary approach isn't happening and the money is not going into the modernization? At what point does it start compromising what you're trying to do, or perhaps this interdisciplinary approach is underway and is going to address this problem?

Dr. LANE. Well, I think that the report, first of all, I think is going to be very helpful, and we need to see what it says. That's the one point I would make.

We certainly will pay close attention to what comes out of this report. I also would anticipate that our fellow agencies in government would look at the report and evaluate their roles in addressing this very real issue.

NIH has a program, a smaller program which supports renewal of academic research infrastructure.

Another thing I would like to say is that I think it's not, it is important to look at academic research infrastructure in the larger context of R&D infrastructure in general.

It would be a shame if some under-utilized space, facilities, equipment, whatever, made available by the federal government due to a downsizing here in one part of the country or another, one laboratory or another, was not at least looked at to see whether that can help address some of the needs of the academic institutions.

The same thing I think is true for industry, as industry reduces its investment in R&D, certainly in basic research, there may be opportunities there that have not been tapped to share some of that infrastructure with the universities.

I think it's at least important to look at that, and I believe the committee is doing so.

Mr. GEREN. Thank you, Mr. Chairman.

Mr. WAMP. Thank you, sir.

The Chair recognizes the republican members in the order that they arrived. I'm very tempted to recognize them in order of grace and beauty and introduce the gentlelady from Maryland, Mrs. Morella to go first.

Mrs. Morella?

Ms. MORELLA. Well, you handled that beautifully, Mr. Chairman.

I do think there is a time and place for freshmen to serve as chairmen. You're doing well.

[Laughter.]

Ms. MORELLA. I'm delighted to have the National Science Foundation here, Dr. Lane, thank you, Dr. Petersen.

You know I have a very soft spot in my heart for what you do, and I notice that in your testimony you quoted very lavishly, I thought it was a very lovely testimony, from the little anecdote



about the spider and with all of the other kinds of projects you're involved in.

But you quote Bronowski, you quote Whitehead, and you said education is your theme.

So I was thinking of a quote by Joseph Addison. He wrote in 1711. He said something like, a human soul without education is like marble in the quarry. None of its inherent beauties come out until the skill of the polisher takes it and makes it shine and brings out every ornamental vein and cloud that runs through it.

Therefore, I see that as kind of the crux of what is the goal and objective of the National Science Foundation, education.

I'm chairing the Subcommittee on Technology which deals with a lot of the overlapping issues that you have, biotechnology and a number of the other areas.

I'm a former educator who also has been pushing math and science in elementary school, particularly as it will appeal to young women and minorities. I know you're doing some of that.

I had the opportunity in December to do something that the Chairman of this Committee has done before, and that is to follow you—I don't know that he did that—in Antarctica at McMudo, so I saw some of the work that's being done with the Antarctica expedition.

I see that my buddy, Mr. Stonner, is here who had the challenge of trying to accompany me, putting those big boots on.

So just two questions. One that deals with how do you evaluate K through 12 where you don't have that much of a thrust in the educational system with regard to math and science?

You're doing some evaluating now. How do you evaluate that you are making a difference and how do you distinguish what you're doing from what the Department of Education is doing?

The second question, with all admiration for the 76 percent waste recycling in Antarctica, the experiments that are being done, you know, in terms of whether we're talking about the ozone level or other experiments, I wondered if you might comment on the plan in the South Pole for design of the geodesic dome that is necessary.

So two things.

How do you evaluate and differ from Department of Education, particularly K through 12.

And your plan in the future for the South Pole infrastructure.

Thank you.

Dr. LANE. Thank you, Congresswoman Morella. It's very nice to see you today. You miss the Antarctic?

Ms. MORELLA. You had a better accommodation than I had in Antarctica but I had a good time.

Dr. LANE. I'm going to ask Luther Williams to join me, who is our Assistant Director for Education and Human Resources, to add a word.

I would like to make a comment, one more comment on education and NSF.

I think the reason it's so important that NSF is involved in education at all levels is because while education is not really viewed as seamless, there are all kinds of gaps people are pointing to, in a very real sense, it ought to be seamless.

And universities, and faculty universities and colleges play a critical role in education at all levels in various ways. Certainly we understand graduate education and undergraduate education.

But in K-12, that's where the teachers get their education. And there's an area where there's room for improvement.

The faculty who are in those classrooms and laboratories are the same faculty NSF supports also to do research and to do graduate education. It's very important. These are the people who are evaluated, peer evaluated by the community and who evaluate others and who understand the substance of the science.

And one of the things missing, at least we've been criticized for having missing in education in the whole spectrum, is the content. And the scientists we support certainly understand the content of science and the importance of science and the integration of science.

The second thing I would like to say is that NSF really stresses in the integration of research and education. We don't see a gap between research and education. We see them as mutually reinforcing, as important to one another.

And if, by research, one means experiential learning, why then it really extends to K-12 as well. We're trying very hard to be sure we have place programs that stress that, that synthesis and that integration.

And one I simply want to mention before I turn to Dr. Williams is the CAREER program where we have pulled together a number of programs that address young faculty in universities, faculty who are just beginning their careers.

This program stresses not only the research that the faculty member does but the education, the teaching plan. It's that kind of a proposal that is reviewed in this program so the winners of our competition in the CAREER programs not only have good ideas about teaching, but they are invested heavily in education in teaching in the laboratories and the classroom as well as in research.

We'll continue to look for ways to make that proper emphasis.

I'd like now to ask Dr. Williams to respond to your question on evaluation.

Dr. WILLIAMS. Thank you, Dr. Lane.

We have now a rather robust evaluation program in place for all of the education efforts in the Foundation. In fact, of the 33 programs that we support, roughly a third of them, a little better than a third of them, are currently under evaluation.

The evaluation is done by our providing support to a third party. That is, they're not done by NSF staff, who then goes out and designs an evaluation.

As you are aware, increasingly, as Dr. Lane indicated, an awful lot of our programming is by NSF working in a partnership with cities, with states, in fact, in 25 states and in local communities and rural areas.

So when the project is designed, they have to in effect do a baseline. In other words, determine the state of math and science education when the project starts. So it's against the baseline of how well the students are performing, the competence, skills, and currency of the teachers in terms of their knowledge of math and

science, the whole infrastructure for delivering math and science education.

We just watch that over time. If we make a five-year award, then in fact our evaluation process starts at zero and covers five years.

The second part of your question was how do we make the distinction between the impact of our programs and those of the Department.

I'm going to answer the question in two regards.

One, it's important that we distinguish our role relative to the Department, but another of our goals clearly, where possible, is to operate synergistically with the Department, because we are leveraging resources that, which are obviously not provided by NSF, they are resident in the schools.

One of the distinctions is that we do an awful lot of programming and the Department does not. NSF has a major responsibility in our budget, as you are aware, approaching \$100 million this fiscal year, for retraining teachers, math and science teachers, particularly, as you indicated, at the elementary level. That's essentially, it's not entirely unique but that is a unit of distinction.

We've also drawn as Dr. Lane indicated, the broad scientific community affiliated with NSF to develop model instructional materials for elementary, middle and high schools math and science programs.

Our informal science education programs are different.

So, in sum, we have a different portfolio, so there's a distinctive niche for education and NSF. They make contributions to math and science education, but it's done from a more generic framework.

Lastly, what we are doing with the two agencies is increasingly, you recognize of course all our programs come through competitive merit review. They operate in a different mode. So obviously we impact a city or a state or a school quite differently. But what we have done quite productively in recent years is found increased ways to actually have our programs operate complementarily.

For example, there's a good parallelism now between NSF support of math and science education at the elementary level and how the Department, that is, local school systems use the Department's Chapter One moneys for math education. Rather than having two operations, there's in effect, one.

Dr. LANE. I would like to answer the second question on the South Pole Station. I would like to ask Dr. Neal Sullivan to join me here, but perhaps I can make a comment.

Dr. Sullivan is Director of the Office of Polar Programs.

I was very pleased to visit the Antarctic for the first time this year, including the South Pole. It was one of my colder experiences.

It was very clear to me, as I knew before going, that the South Pole Station is showing its age. It is a hostile environment down there, and so we are always concerned about the welfare of our scientists and members of the staff who are working in the environment. It's clear that there's need for renewal at the South Pole, and so we certainly take seriously that need and have those discussions underway at the present time.

Second thing I would want to say is that NSF's role there is an historical one. We support science in the Antarctic and we are the U.S. presence on the continent and we certainly take that role seri-

ously and continue to be excited about the science that gets done there.

But I'd like to ask Dr. Sullivan to give a status report on the station planning.

Dr. SULLIVAN. Thank you very much, Dr. Lane. And pleased to meet you, Mrs. Morella. I'm sorry I missed you on your trip to the Antarctic this time. It was between trips for me.

The status of South Pole Station development is basically that we have conducted about a six-year study of all of the aspects of the South Pole Station that Dr. Petersen told you that are necessary for any project to take place or take part in that MRE account competition, so to speak.

And having done that, we've made a presentation to the National Science Board, and the Board has suggested that we continue to plan, to develop our plans on existing funds, and to provide some additional options for funding of the South Pole Station that take into account particularly the interagency and international aspects of possible scenarios for funding South Pole Station.

And we are currently doing that. We'll be making a presentation to the very next meeting of the Polar Task Force, a Subcommittee of the Board.

Mr. WAMP. Thank you, Dr. Sullivan.

Moving along—

Ms. MORELLA. I've used up my time. Thank you.

Mr. WAMP. Thank you, Mrs. Morella. We may have another round, depending on which other members show up, Mrs. Morella, if you could hold your next question until that round.

Another one of my assignments here in the Congress is serving on the Transportation Infrastructure Committee, and serve as Vice Chairman of the Water Resources and Environment Subcommittee which is capably chaired by our next questioner, the Honorable Sherry Boehlert of New York.

Mr. BOEHLERT. Thank you very much, Mr. Chairman.

You know, Mrs. Morella bills herself as a former educator. Someone once said to me, now that she's in Congress, do you think she misses teaching, and I said, no. She still teaching at a more elementary level.

[Laughter.]

Mr. BOEHLERT. I'm one of the students.

Dr. Lane, I want to compliment you on your very comprehensive testimony, but I'm particularly pleased that you told the spiderweb story.

And I think maybe a decade ago, if your predecessors had done more of that, we wouldn't have had the golden fleece awards, and I think we're well beyond that.

I would suggest you get a top ten list and send it to Letterman of these very esoteric types of research projects, and then follow through with an explanation of how important they are to our science base in America.

So I'm really very serious in complimenting you on that.

I've heard a lot of talk about so-called strategic research, and I think that maybe this language is sort of confusing some people because strategic research, basic research, can you give—is there a

distinction, first of all, between the two, and can you give examples of research that is both strategic and basic?

Dr. LANE. Thank you, Congressman Boehlert.

I think we can give many examples. I agree with you that I think the words have been a problem for all of us. Various people mean different things by even basic and applied. Those words even get used differently, and strategic is a relatively new word on the scene, and certainly has caused some confusion. We've had the opportunity to have a good bit of discussion about it.

We try to use the word strategic not as an adjective for research because I think that further confuses things. That suggests it's a certain way of doing science or a certain kind of research.

So what we prefer to do is to talk about research in strategic areas. And NSF supports the more fundamental kind of research, the more basic research in strategic areas.

All that really means is that the research we're supporting is chemistry or physics or biology or sometimes, at the interface, a physicist and a biologist working together on some quite stimulating and important scientific problem. But it happens to be one that we can associate fairly, honestly, with the larger national goal.

I think probably the best example of something that's both is fundamental research in atmospheric science and oceanography that when put together led to a quite sophisticated model of the El Niño effect. That was curiosity, if you like, on the part of the scientists in the communities who really wanted to see the work of years of science and developing understanding about what goes on in the air and what goes on in the ocean brought together in a complex, coupled way to understand the big chunk of the world that includes the ocean/air interface.

As a result of that modeling, it's now possible to predict, with some limitation, El Niño effects, as much as six months in advance.

Now, we'd like to be able to predict further in advance, but that is not the case right now. Even that amount of time does make it possible for the countries that will be immediately impacted or impacted in that time frame, to take some steps, even with regard to crop cycling that can save them immense amounts of money and also lives because of the terrific weather effects that get kicked off by these.

Any more detailed questions on that I would need to turn to my colleague—

Mr. BOEHLERT. No, that's good enough. That's an overview. I appreciate that.

You also know that I have a great deal of interest in undergraduate education. And while I agree with you that faculty research can enhance undergraduate education, I fear that too often it is having the opposite result.

So what I'd like to hear from you are the steps being taken by NSF to ensure that research it is sponsoring is enhancing undergraduate education, and that we don't have a full time faculty engaged only in research and offended by the suggestion that maybe they ought to get in the classroom and do a little teaching.

Dr. LANE. I think it was always NSF's intention, certainly my predecessor's intention to integrate research and education in the

communities that we support. I don't believe NSF ever had any explicit intention of doing otherwise.

We are making this need more explicit, I would say, with programs like the CAREER program that I referred to where you may remember the PYI and the NYI programs, NSF Young Investigator Program, focused on young investigators outstanding researchers nominated by their institutions with great promise in research.

But there wasn't any explicit attention given to how good a teacher they were or if they had creative thoughts about teaching.

The new CAREER program that pulls all of these, the NYI, concept and other young faculty development programs that were developed in the different directorates, it pulls them all together in one program. It allows for flexibility. There are differences from one field to another.

But what the program has in common is that it stresses both the teaching side and the research side.

Mr. BOEHLERT. Are we able to qualify the results? I mean, would you agree that my concern, if not now still legitimate, for darn sure was legitimate a couple of years ago, and that too many of our best and brightest on college campuses were spending all their time, or a disproportionate share of their time, hustling for bucks from you guys and not being in the classroom taking care of the next generation.

I mean, I think that was a very legitimate concern, and I've expressed it before and this is not the first time. Do you have any way to quantify the success you're achieving?

Dr. LANE. Well, Mr. Boehlert, the CAREER program is a new program, so we really don't yet have an opportunity to quantify the success of that program. It certainly is a program that we will evaluate. And in a minute, I'll ask any of my colleagues who had programs in the directorates for a longer period of time if they would comment.

Mr. BOEHLERT. Well, then would you say it's a shared concern, though?

Dr. LANE. Oh, I completely agree. That's the second thing I wanted to say, I completely agree that there is wide perception of a problem here, and there are examples one can point to where the problem is a real one. It's because of the highly competitive nature of the research aspects of the faculty member's career, and the very real requirement, because that's the way our system operates, of the faculty member to obtain external research support, either from NSF or other funding agencies in a peer review system, which is very competitive.

Without that research support, it's simply impossible for researchers in most fields to carry on research activity.

So we feel it is a real issue to be addressed. I often hear from faculty and universities who say, I'd like to teach more, I'd like to give more time to teaching, but I simply can't afford it.

And it's because of the time it takes, in this particular case, the time it takes to write the research proposals, get them funded, get the research going, write the papers, go to the meetings, all things which are very important in the research process. It's a question of balance.

NSF wants to be sure that we have programs in place that assure that proper balance, and in partnership with the universities, improve education, because that is certainly one of our principal goals.

Mr. BOEHLERT. Mr. Chairman, I appreciate your indulgence in letting me conclude this sort of thought.

It's a very serious problem and we have to focus on it, and I don't mean to add to your burden, but I hope you will be attentive to the need for having some sort of quantifiable results that you can share with the Committee.

Because, Mr. Chairman, so many of these youngsters, and I have four children of my own and I know what it's like to go through selecting a school, a college, and gee, you look at the faculty and boy, very impressive list, and if you're going into a particular science discipline, you can't wait to get to that campus and to sit at the feet of the great minds of the world, only to discover that they're not in the classroom. They don't have time for the classroom.

We've got teachers who don't have time to teach, and that is a cause for great concern.

Dr. LANE. Well, Mr. Boehlert, it's certainly not a burden, we don't review this responsibility as a burden. We really believe it is an extremely important issue and I've been reminded that Bill Harris, Assistant Director Math and Physical Sciences, and his colleagues working with the community are putting together a workshop this summer on precisely this issue to address the issue of education.

Mr. BOEHLERT. Well, let me, and this concludes because Mr. Barton has been waiting patiently. I looked around and I didn't see a lot of other members waiting, and so I don't feel too bad about taking a little extra time on this subject area.

Let me give you a six months assignment, if I may. Six months from now, could you take it upon yourself, as an agency, to sort of give us a mid-year report on how you're doing in this particular area?

Dr. LANE. We will do it, Mr. Boehlert.

Mr. BOEHLERT. Thank you so much.

Thank you, Mr. Barton, for your indulgence.

Mr. WAMP. The Chair recognizes one of our younger, senior members, the Honorable Joe Barton of Texas.

Mr. BARTON. Whatever that means.

I've spent my whole career waiting on Sherry Boehlert, so I don't mind waiting another four or five minutes.

[Laughter.]

Mr. BARTON. We're delighted to have you here today.

I noticed in the little summary that we received that it says the purpose of the hearing is to obtain an assessment of the NSF budget request and to explore broader policy issues that may be addressed in NSF authorization legislation. Well, I want to explore some of those broader policy implications.

We have got a review of the National Laboratories underway, and I think it's a given that there's going to be a change in the mission statement in many of the laboratories.

What functions, if any, do you think that the National Science Foundation can undertake that are currently done by the National Laboratories, and if you were to undertake those functions, would you care to hazard a guess about how many dollars you'd like to see reprogrammed into your agency?

Dr. LANE. Mr. Barton, the first thing I would like to say is that there are outstanding researchers working in many of these National Laboratories and the ones I'm familiar with. So they do, it's a personal view, they do represent a national resource.

And also there are many interactions, have been many important interactions, collaborations through the years involving scientists in the National Laboratories and in the universities. So there's good, I think good exchange of information and views and even opportunities for students coming out of the laboratories.

The third thing I would like to comment is that in many cases, the experimental facilities that the university scientists make use of are found in the National Laboratories and are operated by the staff at the Department of Energy, for example.

I think that, of course, I think the Committee understands that NSF doesn't operate any laboratory. The statutes don't permit that.

We enter into, we make grants, we enter into cooperative agreements with academic institutions primarily, and those institutions often operate facilities, laboratories, some of it, but NSF by its statutes does not do that.

Mr. BARTON. But you are beginning a major research equipment program which is beginning to get to the scope of some of the National Laboratories? I mean, you're small but there is a kernel there that is growing. I think you would agree to that.

Dr. LANE. It is certainly true that we have supported some large facilities in the past and are building some right now. They are not operated directly by the NSF, though. They're operated by other organizations, by universities in many cases. But certainly some of the facilities are large, I agree with that.

Mr. BARTON. Well, so far, you've danced totally around the question. Do you just not want to publicly think about some of the functions of the National Laboratories?

Or is it just such a broad statement, you'd like to think about it and respond in writing?

Dr. LANE. Mr. Barton, I certainly would appreciate the opportunity to respond in writing, and I respect the question. It's an important question, and I guess thinking in public sometimes—

Mr. BARTON. I understand.

Begin to think about it because I'm speaking only for myself, but I really do believe that this Congress is going to seriously consider changing the mission statement of the National Laboratories, and in that may be a privatization of some of those assets, may be a termination of some of those assets, but if there are some roles and functions that you think your agency could better utilize and better conduct, we'd like to know about it.

Let me throw another one at you that's even a little bit broader than that. We may eliminate the Department of Energy. We may restructure the Department of Energy.

Would you like to begin to think about some of those activities that might be a good fit with your agency?



And again, you don't have to respond in too much depth, but I'd like for you to think about that a little bit.

Dr. LANE. I'd like to make a similar observation, just stating the obvious I guess, that there's a considerable amount of important fundamental science supported by the Department of Energy in universities as well as the National Labs and much of that science is similar in quality and also in nature to the science that NSF supports.

The Department of Energy has supported these activities because they are relevant to the mission of the Department of Energy but that doesn't keep them from being fundamental science, and that's again another I guess response to Mr. Boehlert. I mean, they really are science areas that can be identified with larger national needs, but they are very fundamental in nature.

So with your permission, I would like to respond to both questions for the record.

Mr. BARTON. Let me kind of package that all in one general question. I believe that the National Science Foundation and the National Institutes of Health, because the majority of your budget goes to so-called small science, and at least theoretically that's all allocated on peer review that's, as we all know, is always done totally on the merits, and there's never any politics involved in that.

I meant that a little bit facetiously but at least the theory is that it's all done on merit. You've got a very good reputation. You don't hear a lot of negative about the management of the National Science Foundation.

And I'm of the belief that if we really seriously look at restructuring the Department of Energy and changing the mission statement of the National Laboratories, that we could very easily come to the conclusion to develop a new department called the Department of Science and Technology, or the Department of Science and Research, and you'd combine some of the research functions at DOE with the National Science Foundation, National Institute of Health, perhaps NASA, and create a super science agency in which the National Science Foundation would be a key leader because you do focus on small science based on merit.

And so it would give an opportunity, if you really are doing things correctly, and I think in general you are, to take the model that you developed as a management tool, and extrapolate it into this super agency. So you might begin to think about that.

Dr. LANE. I certainly appreciate your positive comments, Mr. Barton, about the National Science Foundation. We feel peer review is at the core of, it's one of our core values. We think it's one of the things that has enabled the agency to remain strong through these years and to strengthen in ways perhaps beyond it, what it's budget might suggest as science and engineering capability in this nation.

I think part of the reason also it's been able to do this is because of its independent nature. It has remained a relatively small agency, although it has gotten larger in recent years, and the Director, working Deputy Directors working with the National Science Board, have had considerable freedom in trying to ensure that merit really is the driver of the funding decisions.

Mr. BARTON. My time I know has probably expired.

Do you see a possibility of this super science department? I mean, is that something that has some attraction to you, combining the basic research organizations?

Dr. LANE. Well, Mr. Barton, I think what I would rather say is that there are a number of issues I think that need to be looked at very carefully in making a determination on the possibility of a Department of Science Technology.

And the science enterprise is so important to this country, to its future, I think there's not much disagreement on that, that making large changes in the way in which the federal government involves itself in the support of science clearly is a major step. And I would urge that one approach such a decision very cautiously and lay out all the issues that need to be addressed, keeping always in view the objective of ensuring world leadership of this country in science, engineering and technology, and finding the best way to make that happen.

And I don't claim to know what the best way is to ensure that in the 21st century, but would be happy certainly to work with the Committee to provide whatever knowledge and information that might be helpful.

Mr. BARTON. Well, I thank you, sir, and I thank the Chairmen for their discretion.

Mr. SCHIFF. [Presiding]. Dr. Lane, before I call on the next member for questions, I just want to extend my apology to you and Dr. Petersen and your associates there.

When we scheduled this hearing, it looked like a quiet morning on Capitol Hill, but circumstances change, so I'm pleased that this hearing progressed.

And I want to thank Mr. Wamp from Tennessee for Chairing in my absence and in a while, if we've not concluded, and I don't want to hurry anyone if there's a discussion that we need to carry on, I'm going to have to go on to a markup in another Committee, but I just want you to know that the National Science Foundation is very important to me, and my being tardy to this hearing is not an indication that should be taken otherwise.

I believe next is the gentleman from Minnesota, Mr. Luther, recognized for five minutes.

Mr. LUTHER. Mr. Chairman, I will waive my time. I have no questions.

Mr. SCHIFF. All right, let me turn back to this side.

Mr. Wamp, did you have the opportunity to ask questions while you were chairing, may I ask, or do you desire to do so now?

Mr. WAMP. I'll yield back to you, Mr. Chairman, until the close, at which time I would ask Dr. Lane some other questions.

Mr. BOEHLERT. I've got one more, if I may, as long as everybody's passing.

Mr. SCHIFF. If everyone's had one round—

Oh, I beg your pardon, I didn't see you. Ms. Rivers is recognized, I'm sorry, for five minutes, excuse me.

Ms. RIVERS. Given that I've just arrived, Mr. Chairman, I would also like to submit my questions for the record, rather than ask them now because I missed the first part of the testimony.

Mr. SCHIFF. Everyone's making this too easy on us here, I think, particularly Dr. Lane.

Dr. Lane, if you have some additional time, I want to ask if there's a second round of questions.

Before I do so, I would like to ask two questions myself or make two observations.

One is again, President Reagan, I believe at one point, recommended doubling of funding for the National Science Foundation. I think that indicates the importance we all feel for science.

There are two things on my mind. One keeps coming up about the role of NSF and basic science research in applied science. That is where we're trying to get to product development.

And the materials you gave me about the NSF, that was one of your criteria that you look at was applied research. And my view is, I think we're saying the same thing, my view is there's not a brick wall between basic science and applied science.

It is true that not every basic science research project can have a known end result at the time you commission it, but the idea is you don't know exactly where you're going to be when someone decides this has a practical implication.

So I think the two have to be thought of together. Do you agree with that?

Dr. LANE. Yes, Chairman Schiff. I really do agree and I thank you for your earlier comments. We really enjoyed the opportunity to interact with the Committee today.

I agree that there is this continuum and NSF certainly has strongly shifted to the most fundamental side.

And in our classification, budget classification, we classify very, very little of what we do as applied research. Much of what we call applied is part of what's supported through the SBIR program, for example, not all of it, but much of it.

The example I might use is that an investigator who is looking for a new mechanism of generating coherent light, a new kind of laser, if you like, someone who's experimenting with a new kind of solid material or gaseous material, they have a hunch about what might work, but it's never been tried before. Lots of problems to deal with, a complex issue, and clearly fundamental. Might go, might not go.

Even if it goes, there's absolutely zilch assurance that it would be of any immediate economic importance or applicability. That's basic, in my view.

I would contrast that with a situation where you have a laboratory assigned to take an existing technology, let's use the laser again.

It's a particular kind of solid state laser and it lazes in a particular frequency range. But you want it to be smaller and you want it to use lower power, and you want it ultimately to be cheaper. It's really a product development. That's applied, in my view.

And one can now think through all kinds of scenarios where the people and the ideas need to interact and one can be helpful to the other, and in that regard, I think it can be in some organizations relatively seamless and very important that they not be rigidly separated.

But NSF's definitely shifted to the fundamental, has always been strongly shifted to the fundamental side.

Mr. SCHIFF. Let me just conclude on this first point by saying I agree that the emphasis should be on fundamental science. I'm just saying that you never know when an idea will pop into someone's head that suddenly you have commercial applicability.

And I'm saying we shouldn't take that idea out of that person's head because they didn't begin there.

I'm not suggesting, on the other hand, that the government go into full-fledged competition with private enterprise you know, in product development.

Let me raise my second question with you, if I could.

And what it is is I am concerned about the direction that NSF is going in terms of funding education, scientific education. When I say I'm concerned, you might well ask what's a negative about funding education.

And the answer is, overall, there's no negative. But here is the question in my mind.

There are different levels of government who are interested in fostering math and science education, both generally among minority groups, among exceptional students in the area, and so forth.

The NSF is basically our source of funds for hard research. Whether we call it fundamental or applied is beside the point.

And I'm just concerned that in the area of math and science education, important as it is, and there's no quarrel with that, I wonder if we are risking duplicating what some other groups may be doing at the state and local level, as well as the federal level, and diminishing dollars that have this one source, this one source for the hard research that is going on around the country.

And I realize we want to do both but I have, I just have an impression about where the direction is going and wonder if you'd respond to that.

Dr. LANE. I think that the, obviously a very important question, Mr. Chairman, it's one we talk about internally a great deal because it is an issue of balance and how do we know when we've got the balance right.

I think the special capability that NSF brings to the table here is why the Congress in fact asked NSF back into this in a big way. It is that trying to substantially improve, qualitatively improve education, specially K-12 education across this great United States, it's a very complex enterprise, is going to require not just incremental improvement of the system, but in the views of many is going to require some major jumps, some high risk moves.

Now you can either, in principle at least, just tell the whole nation somehow let's change it all to another kind of system, if you knew what the other kind of system was, and if our nation were such that that's how we did business.

Neither of those things is true, correct? So you have to try some things. You have to do some experiments. You have to take some chances.

And NSF's program in K-12 systemic reform is precisely that kind of program. It's a program that supports states, cities, rural areas, who are willing, interested, committed in running one of these high risk experiments and jointly funding the activity.

So the key word is partnership. Another key word is high risk. Another word is experimental. And then finally, what we think we

do best at NSF is to review the ideas and the people and pick the very best projects using peer review.

So we can't do all the experiments. We can't do everything people want to do, but we try to pick out the ones that we think are best, well-defined, best-defined and have the most promise of success. And then we know some are going to fail and some will succeed and others will learn from the success stories. And we hope in that way to contribute to K-12 reform in the country.

Mr. SCHIFF. I just want to conclude this point by saying I've heard it said in fact by a former associate at NSF whom I met recently that there's no science without scientists, and that is the justification for funding education.

But I would also observe, true as that is, there's no science without scientific research. And the balance is perhaps what you've said we have to strive for.

I'm going to recognize members who desire to ask a second round of questions here.

I think, since I just recognized myself, that Mr. Geren is next, and then Mr. Boehlert.

Mr. GEREN. Thank you, Mr. Chairman.

Dr. Lane, of the \$174 million increase proposed for NSF's research activities in '96, 44 percent is allocated to research initiatives in strategic areas, such as global change research, high performance computing and advanced materials research.

These initiatives constitute approximately half of the whole research budget.

I'd like to ask two questions.

What's the process by which the research initiatives are chosen? Does the NSF program officers alone decide, and then is there resistance in the research community to the large allocation of NSF resources to these sort of areas?

Is it seen as a reduction in resources available for individual investigator awards?

Dr. LANE. Mr. Geren, I'd like to make an opening comment here, and ask my Deputy Director, Anne Petersen, to comment on our process and how we go about sorting these things out.

Some of the strategic areas, global change, for example, high performance computing, arose out of the FCCSET process in the previous Administration.

They were, at their origin, really grassroots activities. They were, I mean, high performance computing really represents, for us, fundamental studies in computer science, applied mathematics, electrical communication engineering, in many fields the most fundamental studies.

So when you ask what's in our high performance computing communication umbrella, it's essentially everything that's in our Computer and Information Science and Engineering Directorate from the most fundamental, including the most fundamental work that we support.

Because it can be argued that a computer scientist trying to answer a very basic question about, if you like, how to handle distributed, large distributed database systems, that can be a very fundamental computer science question.

Clearly it could be relevant, the information could be relevant to the nation's information infrastructure.

So these have arisen out of the community, some of them, the ones I mentioned in particular, biotechnology is another one, advanced materials and processing is a fourth, were part of the FCCSET process.

And NSF was always interested—by always I mean for many years, have been interested in supporting research in these areas, just because it's exciting research.

And so we have continued to identify these because we think they help us explain to the public what the science is good for if the second question is asked.

If the first question is, if it's science, it's good, so I don't need to ask any more questions, well, that's fine. I think that's a reasonable position, but some folks ask, yes, but what's the science doing for us? Help us understand how science helps people's lives.

We think these strategic definitions help do that.

I think our science community understands that. Every field would like more money, and that means some less money for another field. Whether it's a disciplinary field or multi-disciplinary field, so that there'll always be that tension in the community, I think, and that's true in the case of the strategic areas.

Some of our scientists perceive that by us investing in strategic areas, not enough money is available for one or another of the disciplines.

But I would emphasize the disciplines are being funded, many disciplines are being funded under the umbrella of the strategic areas.

Now we do have a process whereby we look at these things now. It's a relatively new process, and I'd like to ask Dr. Petersen just to add a comment to mine on that process.

Dr. PETERSEN. Thank you, Dr. Lane.

Mr. Geren, you've asked a very important question, and it is one that has been asked by some in the community and in the scientific community. It's also been a question among our Board members.

I think there has been confusion about what this means. As Dr. Lane said, one thing that's not true is that research in strategic areas is not different. It's fundamental research that NSF funds.

These areas did emerge from the scientific community. Many of these efforts involve other agencies which helps, and this was the intent of the original FCCSET process and the current National Science and Technology Council process. This helps to reduce redundancy in these important areas so that we don't have multiple agencies funding exactly the same thing, but we have some sense of complementarity in this process.

So there are many things about the broad efforts that are in fact very good for science and very good for the country.

The research that NSF funds in these areas comes from investigators, it comes from their ideas, it is peer reviewed, so in almost all respects, it is not different from other things that we fund at all.

Occasionally, we have a program announcement about some opportunity in one of these areas but in many cases, work that we end up considering being applied to one of these strategic areas of

national interest was an idea that began with an investigator. They may not have been thinking about this area of national need at all, but they simply submitted their proposal. It was successful in the peer review and funded.

In order, though, to keep our eyes on this overall issue of balance, to make sure that we're not, that we always have opportunity for ideas that maybe perhaps don't have some clear area of national interest toward which they could be directed, we want to keep looking at how we're managing this in the Foundation.

And we do have a group composed of the Assistant Directors and Program Directors, called the Strategic Area Planning Group that continually is looking at these very questions.

I chair that group. There are many tough issues that we've considered and we are committed to making sure that we maintain a good balance in the National Science Foundation for the very best science at the important frontiers.

Dr. LANE. Mr. Chairman, could I get in just a very quick anecdote.

Mr. SCHIFF. A brief one if you would so I can go on to the members of the Committee.

Dr. LANE. It's very brief.

One of our very distinguished researchers I won't name recently learned that her research was actually classified under the heading of advanced manufacturing. That's actually the good story because it symbolizes that we're not really directing the researcher to do a certain kind of research or work in a particular area.

But in our evaluation of the research, we could honestly identify the experiment and the materials that are being worked on as appropriate to an area like manufacturing. That's the way we think about the strategic areas.

Thank you, Mr. Chairman.

Mr. SCHIFF. The gentleman's from Texas time has expired.

Mr. Boehlert?

Mr. BOEHLERT. Thank you very much.

Following up, Mr. Chairman, on your questioning, I'd like to make an observation.

Since its inception in 1950, education has been a key component of your mission. As you point out in your own testimony on page two that you've been charged, from the beginning with fostering first rate fundamental research throughout the nation and promoting education and training in science and engineering.

I would observe that I think we've done magnificently well in the educational component in higher education, although it took about a generation to appreciate the value of engineering because that wasn't science, but you finally come around after some nurturing.

But I think we've failed and failed miserably in K through 12. I have yet to see the first study that would put our youngsters in the top ten in achievement levels when compared with our counterparts around the world.

So I would argue very strenuously, Mr. Chairman, that we need to put more money into education.

Now my concern is, and I think it's a concern that underlies the Chairman's statement. We also have an agency called the Depart-

ment of Education. And quite frankly, I wonder what the hell they're doing sometimes in this particular area.

Do they cede this subject area to you, science and math, and say those are for those scientific guys and we're going to take care of the social scientists and history and forget about science and math? Do you interface?

I can recall this, and it was not too long ago when the first time the Director, your predecessor, of the National Science Foundation formally was introduced to the Secretary of Education was at a hearing of this very Subcommittee that was constituted a little bit differently in previous Congresses.

But I wonder and I think the Chairman, this underlies his question. You know, we have limited resources. We want to spend them wisely. And I think you're not doing nearly enough and nearly as well as I would like you to be doing in the area of promoting science and math education in K through 12.

And one of the reasons is because we have been so miserly in giving you the resources you need to do the job.

Mr. SCHIFF. Would the gentleman yield for just one second?

Mr. BOEHLERT. Yes.

Mr. SCHIFF. I appreciate the gentleman yielding.

I just want to take a moment to say that you have exactly expressed my point. It is in no way the questioning of promoting math and science education. It is a question of where are other agencies that also appear to be charged with that versus we appear to be the major hard science funding research, so thank you for emphasizing the point.

I yield back to the gentleman.

Mr. BOEHLERT. Because I can make a very good case for giving you a lot more money in this area, and zeroing out DOE. But that's not what we're here for.

Let's talk about, Dr. Williams, the interfacing or the relationship and getting at the fundamental core of this question.

Dr. WILLIAMS. On the question of relationship and the interface, as you indicated, the hearing to which you referred a couple of years ago, was the initiation of discussion between the Department and NSF that resulted in a memorandum of agreement that was actually signed when Dr. Massey was the Director and Lamar Alexander was the Secretary of Education, so in about '92.

That memorandum of agreement is an interagency operating structure has actually been preserved despite the changes in directorships and secretaries and whatever.

We have a fairly active group that has actually made progress in terms of areas in which we can collaborate.

What has been exceedingly difficult is to get movement beyond discussions of collaboration on programs to what I would term policy decisions and policy issues, but we're making progress there.

There's now a Council of the Deputy Under Secretary of Education, the three assistant secretaries and myself. What I mean by policy speaks to the issue that you were describing. How to actually bring to bear the moneys of the two agencies and effectively support quality math and science education.



That's an important issue because despite the size of the Department's budget, NSF leads in terms of providing resources in K to 12 math and science education, explicitly.

Mr. BOEHLERT. May I interject something right here?

And I appreciate, and this is a big town and complex government we're talking about a trillion, multi-trillion dollar economy, but pardon me for interjecting a common sense approach to it.

Has Lane and Riley and Williams and your counterpart ever sat down over a cup of soup at lunch to talk about science and math education?

The answer is no, I guarantee that. I'd be the most surprised guy in the world if you tell me that the four of you, at one time, on an informal basis, said, look, this is pretty serious stuff, the future of science and research in America and sort of chatted about it, and then sort of parceled out some of the stuff to those endless numbers of commissions and committees and task forces.

Dr. WILLIAMS. Not over lunch.

Mr. BOEHLERT. Well, but you know what I'm driving at, Dr. Williams. I'm not trying to be cute or funny. This is a very serious matter.

Is there one objective study that places U.S. youngsters, Americans, U.S.—Canadians are Americans too -- that places U.S. youngsters in the top ten when compared with our counterparts around the world?

Is there one objective study that does that?

Dr. WILLIAMS. No, not yet.

Two quick responses.

When my reference to the difficulty of now trying to make policy decisions, I was trying to say precisely what you said with respect to getting that agreement. That's where we are now, and it's become very difficult.

I appreciate precisely what you're saying. And the answer is that, no, there's not yet such a study, but I would remind the Committee that we are in fact making progress. The overall performance by American youngsters is improving.

Mr. BOEHLERT. My time is up, I know that.

What can we do to help you?

First of all, you want me to make reservations for the lunch?

[Laughter.]

Mr. BOEHLERT. But isn't there some, Dr. Lane, really, all kidding aside, isn't there some merit to calling up Riley one day and say, hey, look it, let's, I'm going to bring Williams along, you bring your counterpart, the four of us, let's have breakfast or lunch, and sort of talk about this thing, and then have a better feel for where each other is coming from and then task others to follow through on it?

It is scary. I mean, if you're talking about a serious problem in America, and we all talk about them every single day up here, I think that is one of the most serious. And the next millennia is, you know, 57 months away.

We're not talking about eons into the future. And as I am privileged to travel around the world, courtesy of the taxpayers and they're getting a good buy for their buck when I do it because it opens my eyes, I go to places like Hong Kong and Singapore and South Korea, and I say, wow, that's our competition.

And guess what? If we don't shake things up, we're going to be, well, there's some expressions I don't care to use, but we're going to be in trouble.

Dr. LANE. Well, Mr. Boehlert, I think the idea of a lunch sounds very good to me, sort of a general statement, but—

[Laughter.]

Mr. BOEHLERT. I'll pick up the tab, if you want.

[Laughter.]

Dr. LANE. Probably, I appreciate that offer, but I think we will pursue that very excellent suggestion. I know Mr. Riley's strongly—Secretary Riley's strongly committed to quality education, and I expect would be happy to spend some time talking with us about it.

Mr. BOEHLERT. Well, I can sense from what the Chairman has said that you're going to be hearing more about this general area from both of us.

Thank you.

Mr. SCHIFF. The gentleman's time has expired.

Ms. Rivers, do you desire to be recognized?

Ms. RIVERS. No.

Mr. SCHIFF. All right, the lady yields back.

Mr. Wamp, do you desire to be recognized for a second round?

Mr. WAMP. Well, Mr. Chairman, this is your call, but if Dr. Lane has any one of the guests that he brought with him that had a specific area of interest that might need to be put on the record, or presented to the Committee at this time?

I had thought that maybe there was two or three people with you that might want a one-minute. We're used to one-minutes around here, so if you can get anything on the record in one minute that we may need to hear, I thought that might be one way to close the meeting, Mr. Chairman.

Mr. SCHIFF. Dr. Lane, if you'd like to invite your associates to add anything, it's your, I'll turn it over to your call, but I'm going to, first of all, I'm going to turn it over to your call, inviting your associates to make any additional presentation briefly that they might want on the record, if you desire for them to do so.

Dr. LANE. Thank you, Mr. Chairman.

If you'll excuse my back, I'll turn around and see what.

Would anyone care to add anything to our testimony?

[No response.]

Dr. LANE. Well, Mr. Chairman, thanks for the invitation, but I guess not.

Mr. SCHIFF. Seeing no other requests for time, let me just conclude the hearing by saying that although some questions may be raised about direction and emphasis at the NSF, what I gather from the questions I heard from both sides here is that NSF has nothing but friends on this Subcommittee and members of Congress who highly desire to work with your organization for the goals that it was given by Congress.

And for that reason, I really look forward to working with you further, and with your staff.

The Subcommittee hearing is adjourned.

[Whereupon, at 11:16 a.m., Wednesday, February 22, 1995, the Subcommittee was adjourned, subject to call of the Chair.]

# THE 1996 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

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THURSDAY, MARCH 2, 1995

U.S. HOUSE OF REPRESENTATIVES,  
COMMITTEE ON SCIENCE,  
SUBCOMMITTEE ON BASIC RESEARCH,  
*Washington, D. C.*

The Subcommittee met, pursuant to call, at 9:30 a.m. in Room 2318 of the Rayburn House Office Building, the Honorable Steven H. Schiff, chairman of the Subcommittee, presiding.

Mr. SCHIFF. I would like to start by thanking our distinguished witnesses for participating in our second hearing on the National Science Foundation Authorization.

Last week in our first hearing, we invited Dr. Lane, the Director of the National Science Foundation, to remark on the Administration's position in the Fiscal Year 1996 Budget.

Today we have invited outside agency witnesses to provide their support on the Budget.

To summarize, the President's Fiscal Year 1996 Budget Request for total research and development funding is \$72.8 billion, of which Basic Research is \$14.4 billion and Applied and Development Research is \$58.4 billion.

In the Fiscal Year 1996 Budget Request, total civilian research and development increased 3.2 percent to \$34.9 billion.

Civilian Basic Research increased 3.9 percent to \$13.2 billion. Civilian Applied and Development Research increased 2.7 percent to \$21.6 billion.

From within these numbers, the President's request for the National Science Foundation is \$3.36 billion. In Fiscal Year 1995, the National Science Foundation budget comprises approximately 3 percent of the Federal Research and Development Budget of \$72.7 billion.

With that in mind, the National Science Foundation provides about 25 percent of Basic Research funding at universities, and over 50 percent of the Federal funding for basic research in certain fields of science, including math and computer sciences, environmental sciences, and the social sciences.

Additionally, the National Science Foundation plays an important role in pre-college and undergraduate science and mathematics and education through programs of model curriculum development, teacher preparation, and informal science education.

However, I do have some concerns that the National Science Foundation may be focusing too many resources on education support activities and not enough funding on hard, basic research. It's

not that the National Science Foundation has not been doing a good job on this subject, but I have concerns about the role of other government agencies as to what they are doing or not doing, or should be doing.

But in today's fiscal environment, duplication of scarce taxpayer dollars really cannot be tolerated.

I want to take a moment and emphasize, once again, that I very much support the objective of math and science and engineering education. I am just concerned that there are a number of agencies charged with that responsibility, but very few with the responsibility of actually funding scientific research. That is the point I want to make here.

As we move forward toward a markup of our Reauthorization Bill, the Committee will be reviewing all of NSF's programs. We will strive to manage the appropriate balance between basic and applied research.

I believe Basic Research funded through merit-based, peer-reviewed competition results in the best research and the best use of taxpayers' dollars.

On a separate note, I want to express my deepest thanks to the witnesses for their cooperation in complying with the Rules of this Subcommittee with respect to providing statements sufficiently in advance that we could distribute them to all of the Members prior to this hearing. That helps a great deal, and I very much appreciate it.

Now before I recognize our first panel, I would like to turn to other Members of the Subcommittee, and to see if they have any opening statement they would like to make.

I would like to first recognize my Ranking Democratic Member of the Subcommittee from Texas, Mr. Geren.

Mr. GEREN. Thank you, Mr. Chairman. I am pleased to join you in welcoming our distinguished witnesses this morning. Many segments of the Nation's research and education community are represented, and I know that you bring to this Subcommittee extensive knowledge of the programs and activities of the National Science Foundation.

Your testimony will provide us with valuable guidance as we develop authorizing legislation for the Foundation.

The point of departure for this hearing is the NSF Budget Request for fiscal year 1996 which provides growth for the NSF's research activities in what is otherwise a flat budget for federal R&D.

The proposed increases for NSF's research directorates comes at the expense of education programs and research infrastructure support activities.

I am interested in the views of our witnesses on the priorities reflected in this budget.

For example, I would like to explore whether adequate provision has been made for refurbishment of academic research facilities, which has been a matter of special concern to the Science Committee for many years.

In addition to budget priorities within NSF, I encourage our witnesses to provide recommendations regarding any aspect of the

policies and operations of NSF that influence the effectiveness of the Foundation.

We are in a period in which every Federal program is under close scrutiny and must be able to justify its allotment of public resources.

The experience and knowledge of our witnesses this morning provide a valuable resource which will help to place in perspective the role NSF plays in the National Research and Development enterprise, as well as highlight the conditions between NSF programs and national needs.

Again, Mr. Chairman, it is a pleasure to join with you in welcoming our distinguished witnesses, and I look forward to their testimony.

Mr. SCHIFF. Thank you, Mr. Geren.

It has been said over and over again, half in jest and half not so much in jest, that we actually have too few scientists and engineers here in the United States Congress, but we are pleased to have as one of those gentlemen on our Subcommittee Mr. Ehlers of Michigan.

Mr. Ehlers, do you have any opening statement?

Mr. EHLERS. Thank you, Mr. Chairman.

Just a few words in support of what you have said.

Yesterday I was visited in my office by a representative of the Competitiveness Council, a group of manufacturers and academicians, and it was very interesting that the industrial research arm believes that more of the Federal R&D dollars should be going into basic research grants to university and other institutions; and that, even though they appreciate what is being done in the applied area, they really feel that more of the dollars--and they weren't talking about NSF here; they were quite happy with NSF--but research dollars in the Defense Department and the Department of Energy should be parcelled out in the form of research grants.

I happen to agree with that. I think that is a very productive use of our research dollars, as you mentioned in your opening statement.

One other point I would like to make, and I think it is a very important one, is to look at where the future scientists come from. I learned long ago in the academic world that a proportionately larger share of the scientists of this nation and the engineers come from smaller academic institutions, and in many cases liberal arts colleges, who are often struggling to maintain their scientific programs, but yet manage to produce a proportionately larger number of Ph.D.s than many of the larger universities.

I think it is important to keep that in mind, because some of the NSF programs that deal with this and provide funding for research and advanced undergraduate education at the smaller institutions are really a very important part of that, and a very important source of future scientists and engineers for this nation.

With those two points, Mr. Chairman, I will yield back the remainder of my time.

Thank you.

Mr. SCHIFF. Thank you, Mr. Ehlers.

Does the gentleman from Texas, Mr. Doggett, desire to make an opening statement?

Mr. DOGGETT. Thank you, Mr. Chairman.

Only to say that I have had an opportunity to visit with Dr. Mary Anne Fox concerning the important work of NSF, and I am eager to hear your testimony.

Mr. SCHIFF. I thank the gentleman.

A fellow Subcommittee co-chair on this Committee from Maryland, Mrs. Morella.

Mrs. MORELLA. Thank you, Mr. Chairman.

I am very interested in the direction that this hearing is going to take in terms of looking at the budget, and looking at policy directions for the future.

In reference to what Congressman Ehlers said, I see represented here two people who are reflecting the University of Maryland, which is a large institution, but has also not only produced extraordinary scientists but continues to move us competitively toward the future.

The first one is on this panel, Dr. Herman, and on the next panel Dr. Rita Colwell.

So I look forward to hearing our two panelists as we continue with this hearing, and I thank you, Mr. Chairman, for arranging it.

Mr. EHLERS. Would the gentlewoman yield?

Mrs. MORELLA. Yes.

Mr. EHLERS. I would just like to add to that comment. When I taught at the small liberal arts college, we sent some of our best graduates to the University of Maryland's Physics Department, and they have turned into very fine scholars. One of our alumni is in fact on the faculty at the University of Maryland.

Thank you.

Mrs. MORELLA. Mr. Ehlers always knows how to respond.

[Laughter.]

Mr. SCHIFF. Somehow this sounds like the appropriate time to say that I believe the current Chancellor of the University of Maryland was formerly the Chancellor at the University of Illinois in Chicago, which is my alma mater.

[Laughter.]

Mr. SCHIFF. Another member of the Judiciary Committee with me, for whom I hope we both find this a different complexion of a Subcommittee than where we serve together elsewhere, from California, Ms. Lofgren.

Ms. LOFGREN. Thank you.

I would just like to say that I am so happy that the House Judiciary Committee is not meeting today and that I can be here focusing really on what I believe is the future of our country, which is research, and investments in education and knowledge.

I don't have a long statement because I am eager to hear the comments from the panelists, who are very distinguished.

Thank you.

Mr. SCHIFF. I would like to begin now by interviewing the panel.

We have two very, very distinguished panels. First, Dr. Julian Wolpert, who is the Henry G. Bryant Professor of Geography, Public Affairs, and Urban Planning at the Woodrow Wilson School at Princeton University;

Dr. Richard Herman who is Dean of the College of Computer, Mathematical, and Physical Sciences at the University of Maryland; and who is also the Chairman of the Joint Policy Board for Mathematics;

Dr. Roland Schmitt who is Chairman of the American Institute of Physics, representing the Executive Committee of the Council of Scientific Society of Presidents, and who is a former Chairman of the National Science Board; and

Mr. James E. Sawyer, Senior Vice President and Chairman of Greiner Engineering, Inc., Irving, Texas, representing the American Association of Engineering Societies.

We welcome you all.

I want to make the point very emphatically that your written statements were received. They will be a part of the record of this hearing. Therefore, I would urge you to summarize so that the Subcommittee members can go directly to questions.

I would like to begin with Dr. Wolpert.

**STATEMENT OF DR. JULIAN WOLPERT, HENRY G. BRYANT  
PROFESSOR OF GEOGRAPHY, PUBLIC AFFAIRS, AND URBAN  
PLANNING, WOODROW WILSON SCHOOL, PRINCETON UNI-  
VERSITY, PRINCETON, NEW JERSEY, REPRESENTING THE  
CONSORTIUM OF SCHOOL SCIENCE ASSOCIATIONS**

Dr. WOLPERT. Good morning.

I am Julian Wolpert, a Professor of Geography at Princeton University's Woodrow Wilson School. I want to say at the outset that it goes without saying that the "60 Minutes" presentation about what is wrong or what is broken with American undergraduate education represents a severe distortion.

Among the hundreds or thousands of faculty members with whom I am acquainted, there is a very strong commitment, especially of senior faculty, to undergraduate programs. I myself devote at least half of my own time to undergraduate programs, supervision of senior thesis, as well as using, making use of undergraduate assistants on research projects.

Thank you for the opportunity to meet with you this morning on behalf of COSSA, which is the Consortium of Social Science Associations that represents researchers in 90 universities, academic and research institutions, in the social, behavioral, and economic sciences.

As a member of the advisory committee of the National Science Foundation's Social Behavioral and Economic Science Directorate, I have had an opportunity to work closely with its distinguished first director, Dr. Cora Marrett, and her staff.

NSF has a fundamental role in furthering cutting edge research in the social and behavioral sciences. Thus, our research communities and our advisory committee are vitally concerned about NSF and the Directorate's activities and priorities.

My written testimony addresses the advance questions that were posed by the Subcommittee and points out recent major accomplishments of research programs that address the national goals that were outlined in the Carnegie Commission's report "Enabling the Future."

I will simply highlight some of the major points:

First, NSF has had an instrumental role in equipping the current generation of social and behavioral scientists with the rigorous background necessary to conduct hard-nosed and objective basic research, encouraging new ideas and talent, and training the succeeding generation of younger scholars.

There is a lot of work yet to be done on significant problems, so this process should not be allowed to stagnate.

The renewed emphasis on strategic research areas such as human effects of global change, violence and human capital, have had a substantial effect on priorities for the research agenda, but we have a healthy balance and good interaction between the strategic programs and the investigator-initiated programs that needs to be preserved.

The OSTP's National Science and Technology Council, along with NSF, is also reaching out to other governmental agencies to ensure that their research programs in EPA, Department of Transportation, Energy, Defense, et cetera, are sufficiently informed by ongoing studies, new findings, and scientific breakthroughs in the social and behavioral sciences.

Our research community can contribute to their mission, as well.

By way of example, fundamental and basic research by the 1994 Nobel Prize game theorist John Harsanyi, John Nash, and Reinhard Selden, helped the government reap a net of over \$10 billion in the recent FCC auction for awarding licenses for the use of the electromagnetic spectrum for new services.

A recent NSF grantee, Cal Tech's Charles Plott, was responsible for the economic experiments that were basic research that helped the FCC eventually to select the final auction design.

Other potential applications include airport landing rights, pollution rights, and resource use on the Space Station. This is a triumph of market mechanisms over bureaucratic decision-making.

However, we mustn't forget that these achievements came from initiator-driven basic projects.

The role of the social, behavioral, and economic sciences is very substantial in all of the seven strategic areas that are prominent in NSF's fiscal year 1996 budget proposals.

These areas all offer the opportunity to put to very practical use the methods like game theory and the FCC auction that will help the Nation retain its scientific leadership and cope with the 21st Century.

The NSF will shortly establish a multidisciplinary, multiagency Center for Research on Violence, at the suggestion of Congress, and as structured by experts in the research community.

Basic research topics will include accurate measures of criminal activity, patterns, trends and consequences of crime, family violence and childhood aggressive behavior, and the effects on crime of drugs and alcohol.

In collaboration with industry and the engineering directorate with whom we work very closely, the social and behavior economic sciences have also developed a program on quality organizations to examine potential improvements in management structures to enhance their competitiveness in the international economy.

Some of the most prominent social scientists were recipients of NSF graduate fellowships. It is vital to continue this program, es-



pecially as the Department of Education's Harris and Javits Fellowships are eliminated.

The Fellowships have succeeded also in attracting significant numbers of students from minority backgrounds into some of the social and behavioral science disciplines that NSF needs to continue to recruit minority members and women across all of the sciences.

The needs in the social, behavioral, and economic sciences for facilities and equipment are not as great as in the other sciences—except for sophisticated computers, which we use a good deal.

The research community strongly supports a competitive, merit review program to ensure that increased funding for facilities does not occur at the expense of funds for basic research.

A multi-agency approach through the National Science and Technology Council should help to provide that safeguard.

In conclusion, science policy for the U.S. in the 21st Century must pursue an integrated strategy that puts society and people first over purely technocratic solutions. To maintain the U.S. as a world leader in science, economic prosperity, and as a beacon of Democracy, our priorities must emphasize greater knowledge about people and their livelihoods and communities.

Complex systems of human interaction and economic, social, and political decisions require continued study and increased investment.

Research on people and societal issues like crime, job training, education, race, and the environment must be part of a forward-looking U.S. science strategy. In all of these areas, NSF remains as a fundamental participant and therefore must receive adequate funds to carry out these activities on behalf of the Nation.

We urge that the Reauthorization bill that emerges from this Committee, and eventually from the Congress, provide the funding necessary to maintain NSF as a premiere basic science agency in the world.

Thank you for the opportunity to present our observations and views. I would be happy to answer any questions the Committee might have.

Thank you.

[The prepared statement of Dr. Wolpert follows.]

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## CONSORTIUM of SOCIAL SCIENCE ASSOCIATIONS

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### TESTIMONY OF

JULIAN WOLPERT, Ph.D.

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GEOGRAPHY, URBAN PLANNING AND URBAN AFFAIRS  
WOODROW WILSON SCHOOL  
PRINCETON UNIVERSITY

on behalf of the

CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS  
(COSSA)

on the

REAUTHORIZATION

of the

NATIONAL SCIENCE FOUNDATION

SUBCOMMITTEE ON BASIC RESEARCH  
COMMITTEE ON SCIENCE  
U.S. HOUSE OF REPRESENTATIVES

HONORABLE STEVE SCHIFF, CHAIRMAN

MARCH 2, 1995

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American Anthropological Association • American Economic Association • American Historical Association • American Political Science Association  
American Psychological Association • American Society of Criminology • American Sociological Association • American Statistical Association  
Association of American Geographers • Association of American Law Schools • Law and Society Association • Linguistic Society of America

Mr. Chairman and Members of the Subcommittee:

I am Julian Wolpert, Henry G. Bryant Professor of Geography, Urban Planning and Urban Affairs at the Woodrow Wilson School of Princeton University. I am a former President of the Association of American Geographers and a member of the National Academy of Sciences. I have been a member, since its inception in 1992, of the Advisory Committee for the Social, Behavioral and Economic Science Directorate at the National Science Foundation.

I testify today on behalf of the Consortium of Social Science Associations (COSSA) which represents more than 90 professional associations, scientific societies, universities and research institutions concerned with the promotion of and funding for research in the social, behavioral and economic sciences. COSSA functions as a bridge between the research world and the Washington community. A list of COSSA's Members, Affiliates, and Contributors is attached.

During the past 13 years, one of COSSA's major functions has been to advocate for the improved status and funding of the social and behavioral sciences at the National Science Foundation. In March 1989, Nobel Prize winner, Professor Herbert Simon of Carnegie-Mellon University, testifying to this Subcommittee, revived the idea of a separate directorate at NSF for the social and behavioral sciences. In October 1991, after much discussion and debate, NSF Director Walter Massey created the Directorate for the Social, Behavioral, and Economic Sciences (SBE).

COSSA has worked closely with Dr. Cora Marrett, the splendid first Assistant Director for SBE, to help promote the Directorate within the Foundation and with the external science and policymaking community. Enhancing the status and funding for the SBE Directorate are the primary goals for COSSA in the NSF reauthorization because research conducted in these disciplines is a valuable national resource. We would therefore oppose any efforts to reorganize NSF that would diminish the SBE directorate.

COSSA would like to take this opportunity to express our appreciation to the Subcommittee for its continued strong support of the NSF and its social and behavioral science component. COSSA also commends the Subcommittee for its strong concern for individual investigator initiated research projects at NSF.

The past three years have seen tremendous ferment in national science policy. The end of the Cold War justification for federal support for science, continued fiscal constraints, and repeated calls for research related to national goals have dominated the debate over the future of U.S. science policy and NSF's role in that policy. Even with the shift in the Congressional political landscape that discussion will no doubt continue.

As the flagship agency dedicated to promoting the health of science, NSF plays a vital role in ensuring the continued production of new ideas and scientists to produce those ideas. The principal purpose of the NSF must remain supporting basic research and developing scientific talent. NSF must continue to incubate and nurture new and promising ideas. Without that, this nation does not develop intellectually, and our technology stagnates, rather than innovates.

Although representing only 3 percent of the federal research and development budget, NSF support for experiments and investigations into subjects without evident short-term payoffs has been vital to U.S. leadership in science and technology. The new NSF strategic plan maintains the Foundation's strong role as the major supporter of individual investigator initiated basic research.

For research in the social, behavioral, and economic sciences NSF remains a vital source of federal support. It provides close to one-third of all federal support for these disciplines; over 60 percent of the support for academically-based basic research in the social sciences; and over 90 percent in such areas as archaeology, political science, and linguistics.

#### Setting the Scientific Agenda

In the debate concerning an emphasis on research in strategic areas, the real question is who sets the research agenda? For over 40 years, with some exceptions, the heart of NSF's system included the scientific community interacting with NSF, usually its program officers, to generate new ideas and projects worthy of support. Lately, there is a perception among scientists and policymakers that the system has been altered to an approach where research topics for investigation are chosen by non-scientists.

The genius of American science has been the richness and diversity of the enterprise steered by scientists seeking answers to important questions. Yet, pressures for scientific and technological advances create the requirement at NSF for multidisciplinary research in strategic areas and for increased cross-directorate cooperation as well as increased interaction with other agencies, state and local governments, and the private sector. In addition, in an era of constrained resources, the new National Science and Technology Council (NSTC), because of its coordinating and budget-setting role, has become a major player with OMB in determining research agendas and research budgets. Thus, scientific agenda setters within the government must make specific efforts to consult with researchers, so that priorities reflect new findings, new tools, and areas where scientific breakthroughs of unanticipated impact seem possible. At NSF, for the most part, this has happened.

In the SBE sciences, research continues to examine the ever more complex and important human dimensions of issues and generates new knowledge and insights to help us understand human commonalities and human differences. Basic research in these disciplines also develops information that can later be utilized by policymakers to formulate solutions to individual and societal problems.

For example, the Federal Communications Commission's auction to award licenses for use of the electromagnetic spectrum for new services was designed almost entirely by experts in game theory, according to *The Economist*, "one of the economic profession's more esoteric fields." Game theorists John Harsanyi, John Nash and Reinhard Selden received 1994's Nobel Prize in economics. The use of what the *Wall Street Journal* called "the cutting edge of economic theory," helped the government reap a net of over \$10 billion, far more than previous auction results. Charles Plott of the California Institute of Technology, one of the NSF grantees who conducted the

economic experiments that helped the FCC select a final auction design, has noted that game theory "could apply to anything that requires grouping things together, and a speedy conclusion," such as airport landing rights, pollution rights, and the right to use resources on the space station. He also called it a triumph of market mechanisms over bureaucratic mechanisms.

In addition, large social science data collections supported by NSF, such as the Panel Study of Income Dynamics, the General Social Survey and the National Election Studies, have provided researchers sources of information to study such issues as unemployment, economic decisions, family structure, non-voting, and many others to inform policymakers.

#### Basic Research in Strategic Areas and the SBE Sciences

The seven areas NSF identifies as strategic areas still dominate the Foundation's FY 1996 budget proposal. Yet, these areas represent opportunities for basic research to provide the information that, like game theory and the FCC auction, will help the nation move forward and cope with the 21st Century. The role of the social, behavioral, and economic sciences in those strategic areas has slowly increased as the SBE Directorate becomes more vitally involved in multidisciplinary, cross directorate, and Foundation wide activities. The SBE Directorate has a role in all seven areas, more than any other NSF research directorate.

Clearly, there is room for even greater involvement and enhanced resources. This has happened within the area of Global Change and the Environment where increased attention to policy sciences and integrated assessments have become an integral part of the research agenda. In testimony to the Senate Energy Committee on March 30, 1993, the importance of these factors was referred to by Office of Science and Technology Policy Director John Gibbons, who noted "We need to expand research on the effects of global change, including research on human health, settlements, and societal response."

In FY 1995, SBE will begin support for a set of centers on the human dimensions of global change that will include international activities designed to strengthen interdisciplinary approaches through collection and examination of international data sets and research collaborations. In partnership with the Biological Sciences Directorate, SBE is also establishing a Center for Environmental Decision-Making Research and supporting research to build social and economic understanding into the long term ecological research sites supported by NSF for many years.

Just as the human dimensions of global environmental change have been accepted as part of the research agenda of that important national research program, it is equally important to include the human dimensions of technological change in the advanced manufacturing initiative. As Dale Compton, Distinguished Professor of Industrial Engineering at Purdue University, has noted: "The problem in manufacturing is not technology, it is management and the need to change large organizations, motivate people, and build work teams." All of these are subjects of social and behavioral science research. The problems, Compton noted are "too important to be left to the engineers." Robert Solow, Professor of Economics at MIT and Nobel Prize winner, has made the same point in testimony to the House Science, Space and Technology Committee. Working with

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the Engineering Directorate, SBE has supported basic research on understanding social, management and educational issues in manufacturing.

The SBE sciences' role in the High Performance Computing and Communications (HPCC) initiative is complemented by research on cognitive science and intelligent systems, also supported by the Computer, Information Science and Engineering Directorate. These studies ascertain human abilities to receive, store, process, and communicate information and to interact with artificial systems designed to deal with massive volume of information. SBE is also providing support for the Digital Libraries project for research on using large, complex data bases.

COSSA strongly supports enhanced basic research on the social consequences of technological change. The HPCC and the growth of computer networks and personal communications systems, will have repercussions for the nation's social and political fabric, as did other previous major technological changes. In the past, the nation rarely spent resources to contemplate these consequences. At the moment, support for social impact studies is negligible as the nation rushes headlong into the promised land of the technological transformation of our lives. We should set aside resources, as the Human Genome Research Program does, to explore the social, economic and legal issues of these changes.

In Biotechnology, SBE is supporting research on determinants of public attitudes and decision-making related to advances in this area. It also supports research on ethics and values so deeply connected to using the results of this expanding technology.

The social, behavioral and economic sciences are also heavily involved in the Civil Infrastructure initiative. Again in cooperation with the Engineering Directorate, SBE supports basic research on determining how economic and social needs and management methods interact with physical infrastructure. In addition, SBE scientists are exploring how to achieve a better understanding of the political, legal, and institutional interactions that sometimes impede physical improvements.

Working with the Education and Human Resources Directorate, SBE scientists are conducting basic research on the description, modeling, and development of learning, and of processes underlying human learning, such as concept formation, problem solving, social cognition, attitude formation, and motivation. Studies of teacher attitudes, beliefs, knowledge and cognition, classroom characteristics, and conceptual change are also part of the research agenda in the education strategic area.

#### Examples of SBE Basic Research to Meet National Goals

The NSF initiatives define national goals focusing on technology and economic competitiveness. There are alternative concepts of national goals. The Carnegie Commission report, *Enabling the Future: Linking Science and Technology to Societal Goals*, notes four major societal goals to which science and technology can contribute:

- ♦ Quality of Life, Health, Human Development and Knowledge
- ♦ A Resilient, Sustainable, and Competitive Economy
- ♦ Environmental Quality and Sustainable Use of Natural Resources
- ♦ Personal, National and International Security

Within each of these are researchable areas such as: education and diffusion of knowledge; cultural pluralism and community harmony; full employment and workforce training; international cooperation and action; maintenance of urban infrastructure; personal security and social justice; and national and international security. These are topics for which social, behavioral and economic science research has made significant contributions, and continues to make valuable contributions.

If we examine some of the results of SBE research, much of it supported by NSF, it has pursued many of the goals cited by the Carnegie Commission. The examples that follow are not the results of a single project, but often represent cumulative developments where basic research projects have provided a useful body of knowledge.

Psychological and demographic studies combined with methodological advances in survey techniques have created the market research industry which continues to utilize this knowledge to establish such innovative businesses as CLARITAS and American Demographics. This research has also been translated into the multi-million dollar polling industry which has explained political, social and economic behavior, not only in America, but in the rest of the world. In addition, basic research on political behavior helps the media industry interpret elections and other political events.

The National Center for Geographic Information and Analysis has been supported by NSF for a number of years. Its research and training activities have helped nourish a \$1.8 billion Geographic Information Systems industry that has transformed urban and rural planning, ecological analysis, and resource management, in the United States and other industrialized countries.

Sociological and anthropological research on race, ethnicity and multiculturalism have provided companies with the information and expertise to interact more effectively with increasingly multicultural workforces and markets. Given the demographic projections about the increased diversity of the U S workforce, these programs have become an important part of business planning. In addition, basic research on conflict resolution and risk taking has been utilized in mediation and negotiation efforts.

The NSF Science and Technology Center for Research on Cognitive Science at the University of Pennsylvania has attracted the support of nine major corporations interested in basic research on language processing, language acquisition, and perception and action. A "grasp laboratory" is conducting research on visual and tactile activities of robots. Prior research on computational linguistics provided the basis for pen based computing, a product now entering the marketplace.

Basic research on economics and sociology has changed the way businesses think of the

functioning of financial markets, how people react to various economic stimuli, how monetary and fiscal policy work, and how organizations make decisions. In addition, research by economists has greatly contributed to our understanding of the critical importance of technological advances to the growth of American productivity and the impact of investments in science.

Industrial and technological growth in a global economy is inevitably a public private partnership, and the creation of a climate for its success depends on research on politics, law, regulatory systems, and governmental processes and institutions. This research also helps provide for effective and successful negotiation, collaboration, and trade in the international arena.

Finally, research conducted by SBE scientists underpin training in all fields. Basic research has impacted how teachers teach and how people learn. Studies in cognitive science have provided knowledge about teaching and learning from the pre-school to the graduate level. Studies in the history of science and technology, and ethics and values in science equip students with valuable information about how science developed and how science should be conducted.

The SBE sciences have also demonstrated that their research agendas cross into the other agencies of the Federal government which utilize much of the basic research and apply it to specific problems of concern to them. These include: Department of Defense concern with personnel training, human relations, visual and auditory perception, and human factors engineering research; Department of Justice concerns with crime, criminal behavior, and the criminal justice system; Department of Education interest in teaching and learning and testing and assessment research; Department of Health and Human Services interest in health and behavior and poverty research; and Department of Labor interest in workforce, workplace and organization research.

#### New Thrusts in SBE Research

Aside from the basic research supported in the already identified strategic areas, the SBE directorate will move forward focusing in new areas where basic research has long been underway, but that will now achieve more support.

At the suggestion of Congress and nurtured by the research community, NSF will establish a Center/Consortia for Research on Violence in FY 1995. Arising from the recommendations of a National Research Council report, *Understanding and Preventing Violence*, the SBE directorate has planned a multi-disciplinary, multi-agency effort. Among the topics for basic research under consideration are: obtaining more accurate measures of criminal activity; patterns, trends, and consequences of crime; the impact on the commission of crimes of such items as increasing the prison population, childhood aggressive behavior, family violence, drugs and alcohol, community characteristics, social and economic structure and organization, community culture, gangs, and firearms.

In collaboration with industry and the Engineering Directorate, SBE has developed a program called *Transformations to Quality Organizations*. Multidisciplinary teams are conducting basic research investigating how organizations can improve their management structures and



quality controls to compete in the international economy. The research techniques include computer simulations and modeling, building interdisciplinary methodologies, developing benchmarks, on-site assessments, longitudinal data collection, and case studies.

Scientific research on *democratization* seeks to examine the factors that facilitate or impede democracy. The changes occurring around the world provide a natural laboratory for social science research on the social forces contributing to the many important transformations taking place. A NSF workshop held in 1993 produced a report urging enhanced resources for research on factors that impede the expansion of freedom in authoritarian regimes, facilitate democratization in transitional societies, threaten the continued viability of unstable democracies, and maintain democracy in mature states such as the United States. Other topics for research include: the role of market transitions, the rule of law, global system factors, alternative routes to democracy, and democratic political institutions.

The *human capital initiative* is a multidisciplinary effort to construct an agenda supporting fundamental research that considers the economic, psychological, and social contexts that influence the development of human capital. This term, utilized by Nobel prize winning research in economics, refers to the intellectual, physical and emotional capacities, potentials and resources for people to become productive citizens. Six key areas that together represent the major contextual influences on human capital have been identified: neighborhoods, family, workplace, education, discrimination, and economic factors. Basic research that provides an understanding of failures to develop human capital not only will have strategic value for solving critical social problems but also will make significant theoretical contributions by developing models of human motivation and performance that incorporate psychological, social, and economic factors rather than focusing on only one domain.

NSF continues to lead in support of the global effort to document *human genetic diversity*. This multidisciplinary research program, including support from the SBE directorate, promises to illuminate the history of human migrations, relationships between culture and language, and the genetic bases of susceptibility and resistance to diseases. Biologists, population geneticists, anthropologists, ethicists, are all working together on this important project that its champion Luca Cavalli-Sforza suggests will "undercut conventional notions of race" that cause discrimination, as early results indicate that genetic variation between members of a population is far greater than that between populations.

SBE scientists are taking the lead in developing the performance measures and metrics to help agencies comply with the Government Performance and Results Act (GPRA). Using techniques that have helped to measure the economic and social returns on investment in scientific research, SBE scientists and their colleagues from other disciplines are exploring the issues raised by GPRA and its emphasis on accountability.

### Education and Human Resources

COSSA agrees with NSF's budget strategy of consolidating the enormous gains made by the Education and Human Resources Directorate over the past decade. The on-going evaluations of current programs must occur to determine what works and then decisions should be made as to where to move with enhanced resources for the future.

Although there has been some improvement in recent years, unfortunately, most discussions of science education continue to exclude the SBE sciences. The AAAS Project 2061 and the Westinghouse Talent Search Science Contest are exceptions to this rule. The EHR directorate is slowly coming around, but it has not been an easy battle. COSSA does not have any problem with increased funding for science education, unless it comes at the expense of research.

NSF has been the major source of support for graduate students in the SBE sciences. Graduate fellowships provide direct support to individual students. The new graduate traineeship program provides support to academic departments and allows some flexibility in modes of student support. COSSA strongly supports providing NSF fellowships to graduate students, particularly as other sources, such as the Department of Education's Harris and Javits Fellowship programs, are eliminated.

NSF has made a major commitment to attract students from minority backgrounds into science, thus ending a significant waste of human resource potential. Many people, including some at NSF, believe that the SBE sciences are fields where Black and other minorities have prospered, compared to the natural and physical sciences. This view, which treats the social and behavioral sciences as one discipline, masks marked differences that should not be overlooked. Some disciplines such as sociology and psychology do remarkably well in attracting a diverse population to their profession. Others do not do as well. NSF needs to continue to help interest minorities in all sciences through their human resource programs.

### Facilities

Before I conclude, let me say a word about facilities. Although the needs in the SBE sciences for new and renovated physical facilities may not be as great as in the other sciences, a competitive merit-reviewed program should be the answer to increased earmarking in appropriations bills for facilities. COSSA agrees with NSF that a multi-agency approach through the National Science and Technology Council must occur. However, **any increased funding for facilities should not come at the expense of funds for basic research.**

The SBE sciences are more interested in an enlarged instrumentation program. Despite a tendency to overlook it, equipment needs in the social, behavioral and economic sciences are increasingly complex. Our researchers now require sophisticated computers that can handle large bodies of data and complicated multivariate modeling and econometric procedures. Psychological and cognitive scientists increasingly need access to advanced machinery. Research in linguistics requires technologically advanced information processing systems.

In addition, analysis of human behavior and organizations requires dealing with very large complex data sets, and that as the sciences develop, they demand both more expensive (longitudinal, cross-cultural) data sets, and more expensive computational resources for analyses. These instrumentation needs for SBE are increasingly important and increasingly costly.

#### Conclusion: An Integrated Science Policy

Science policy for the United States in the 21st Century must pursue an integrated strategy that focuses on the physical, natural, behavioral and social aspects of what it will mean to function in a technologically oriented society still dominated by interactions among human beings. As the current research initiative on global change has demonstrated, focusing research on all the sciences should be an imperative of U.S. science policy. Thus, to maintain the United States as a world leader in science, economic well-being, and as the beacon of democracy, enhanced resources devoted to gaining increased knowledge about humans and their communities must be a priority.

Any fundamental science policy must include significant investments to explain the behaviors of human beings as they interact with each other and with their social, political, economic, and technological environment. It must include research on those social, political and economic systems themselves. In addition, the paradox of an increasingly interdependent, yet competitive nation-state system also compels a continued research focus on all aspects of the international system.

Technology will not solve our "people" and "societal" problems. All technological advances are accompanied by upheavals in human relations and societal relations. Thus, there is a clear need for fundamental studies of the social, legal, and ethical implications of new technological breakthroughs.

Complex systems of economic, social and political decision-making by individuals and organizations require further study and increased investment by science policy makers. The biological revolution predicted for the next century may discover genetic markers to explain predispositions toward certain behavior, but it will not account for all of the variance. Social, political, and economic factors will still impact national problems such as crime, race, poverty, job training, education, health, environment, rural and urban development, and an aging population. Research on these factors must be part of any U.S. science strategy.

In all of these, the National Science Foundation remains a central actor to support the conduct of this research and therefore, must receive adequate funds to carry out these important activities for the nation. We hope that the reauthorization bill that emerges from this Committee, and eventually from this Congress, provides funding necessary to maintain NSF as the premier basic science agency in the world.

Thank you for the opportunity to present our views. I will be happy to answer any questions the committee may have.

## BRIEF BIOGRAPHICAL STATEMENT FOR JULIAN WOLPERT

Julian Wolpert is the Henry G. Bryant Professor of Geography, Public Affairs and Urban Planning at Princeton University's Woodrow Wilson School. He received his B.A. at Columbia and his M.A. and Ph.D. degrees at the University of Wisconsin.

He was elected to the National Academy of Sciences in 1977 and has been a Fellow of the American Association for the Advancement of Science, the Guggenheim Foundation, and the Smithsonian Institution's Wilson Center.

Dr. Wolpert's current teaching and research is focused on location theory, transportation and land use issues, and environmental management. He is the author of many books, monographs and articles on these and other subjects.

He is a Past President of the Association of American Geographers. Currently, he serves as a member of the Advisory Committee of the National Science Foundation's Social, Behavioral and Social Science Directorate.

# CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS

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Society for the Scientific Study of Religion  
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Southern Sociological Society  
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University of Tennessee  
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Tulane University  
University of Washington  
University of Wisconsin, Madison  
University of Wisconsin, Milwaukee  
Yale University

Mr. SCHIFF. Thank you, Dr. Wolpert.  
Dr. Herman?

**STATEMENT OF DR. RICHARD HERMAN, DEAN, COLLEGE OF  
COMPUTER, MATHEMATICAL, AND PHYSICAL SCIENCES,  
UNIVERSITY OF MARYLAND; CHAIRMAN, JOINT POLICY  
BOARD FOR MATHEMATICS, WASHINGTON, D.C.**

Dr. HERMAN. Good morning, Mr. Chairman, and Members of the Subcommittee.

I am Richard Herman, Chair of the Joint Policy Board for Mathematics, which represents three associations of mathematical scientists whose concerns encompass research, education, and applications.

Thank you for this opportunity to talk to the Subcommittee about the reauthorization of the National Science Foundation.

I suppose before beginning I should thank Congresswoman Morella for the kind remarks about the University of Maryland.

Let me start by giving our strong endorsement to NSF's new Strategic Plan. "NSF in a Changing World."

Most importantly, it reaffirms NSF's unique responsibility for maintaining the Nation's world leadership in science, mathematics, and engineering and achieving excellence in science, mathematics, engineering, and technology education.

The Foundation plays a key role in ensuring the health and vitality of the mathematical sciences, and in particular provides virtually the only federal support for mathematical research, fundamental mathematical research, indeed as the Chair has noted.

We also support the NSF's fiscal year 1996 budget request. Even with a modest overall growth of 3 percent, the proposal would allow a 7.6 percent increase in research and related activities.

We are concerned that the 1 percent decrease in education and human resources would adversely affect our undergraduate program, but agree with NSF's assessment that, given the rapid growth in other education and human resources programs, there is now a need to evaluate them carefully and ensure that they are on the right track.

Let me address three policy issues that we ask the Subcommittee to consider as it writes Reauthorization legislation, starting with some thoughts on the nature and the relationship between discipline-oriented research essential to ensuring world leadership, and thematic programs designed to address specific national needs.

In the correspondence inviting me to testify today, the following question is posed:

Is the balance between curiosity-driven research and strategic research at NSF correct? And what criteria should be used to determine the proper allocation?

This is a critical area for your consideration, particularly as you exercise carefully your oversight responsibilities.

I would like to suggest that the issue be looked at terms of the two research goals adopted in NSF's strategic plan.

Maintaining world leadership and promoting the discovery, integration, and dissemination, and employment of new knowledge and service to society;

Curiosity-driven research often leads to contributions toward meeting societal needs. Moreover, strategic research, which is more properly labeled research in strategic areas, can enhance the pre-eminence of the research enterprise.

As a practical matter, to facilitate service to society some federal research activities are organized into thematic programs associated with areas that have been identified as priorities through a political and scientific process.

It is appropriate for NSF to have a special responsibility for the fundamental research components of these programs. NSF really is in the best position to engage the academic community in the most promising basic research to address the scientific problems that arise in these and other areas of national interest.

We recommend that, rather than seeking a balance between thematic and non-thematic programs, NSF be held accountable for how its aggregate effort is achieving its goals and addressing societal needs.

We are concerned that rigid guidelines for the allocation of the budget between thematic and non-thematic programs would compromise the agility of NSF and diminish the capacity of the research enterprise to respond to, as yet, unforeseen scientific opportunities and societal needs.

Turning to a second issue of undergraduate education, I know that members of the Subcommittee have expressed concerns about the quality of education at our universities. At this point I would like to refer to Dr. Wolpert's comment about the "60 Minutes." I can only second his sentiment in saying that this is a gross distortion of what takes place at most universities.

The mathematical community believes in the paramount importance of undergraduate education and has been working consistently to improve it.

While NSF's Education and Human Resource programs have been growing rapidly in recent years, most of the new funding has been devoted to K through 12 activities—and deservedly so—but we suggest that the NSF's division of undergraduate education is underfunded relative to its importance to educational reform at all levels.

We urge the Subcommittee to encourage an expanded division's curriculum development and faculty enhancement program as the most effective way for NSF to help strengthen undergraduate education.

Undergraduate education is critical for the workforce in general and the next generation of teachers in particular. For over a decade, the mathematical sciences community has been working to revitalize a key ingredient in undergraduate education. The calculus course.

NSF's leadership and support for this effort have been absolutely critical to its success. A recent assessment conducted by the Math Association of America shows broad adoption of the reform efforts, and evaluation shows that student are learning more and continuing their study in mathematics—especially women and minorities.

The movement to improve the teaching and learning of calculus is still fragile and requires support to sustain momentum. However, the success of the program has prompted educators to identify

other courses and disciplines where NSF's involvement could leverage significant change for the better.

The Division of Undergraduate Studies is now supporting curriculum initiatives in introductory chemistry and interdisciplinary mathematics, for example.

On one final topic, then, I would like to turn to High Performance Computing. High Performance Computing technologies are actually revolutionizing research in many areas of basic science, mathematics, and engineering. This potential was identified in the early 1980s, long before the Federal Government established a multi-agency program.

Since that time, NSF has taken the lead in providing academic researchers with access to advanced computing technologies and investing in the mathematical and computational research that enables their use in solving highly complex problems.

NSF continues to help the research community through the cost and technical barriers that prevent bringing the full advantages of High Performance Computing technologies to bear on key problems on the edges of the intellectual frontier.

We urge the Subcommittee to champion NSF's involvement in High Performance Computing as an essential component of the Nation's basic infrastructure.

Many of NSF's research divisions and support work characterizes part of the HPC program. The mathematical sciences basic research carried out under the HPCC banner has led and continues to lead to new mathematical methods, algorithms, and conceptual models motivated by the multitude of issues that arise in the development and use of more powerful and interconnected computing environments.

These interactions are stimulating new creativity and progress in many fields as researchers chip away at the so-called "grand challenge" problems like atmosphere and ocean modeling, molecular design, and improved understanding of physiological processes.

NSF is truly inventing the future of basic research when computational and numerical laboratories are able to replace expensive facilities such as wind tunnels used in aircraft design.

In conclusion, Mr. Chairman, let me thank you and the Members of your Subcommittee for the supportive comments you have made on behalf of the National Science Foundation. I hope you will agree that it is a valuable national resource for meeting our research and education needs in a comprehensive and coordinated fashion.

Thank you very much for your consideration of my remarks. I would be pleased to answer any questions you might have.

[The prepared statement of Dr. Herman follows.]



# JOINT POLICY BOARD FOR MATHEMATICS

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## TESTIMONY ON THE REAUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION

The Hon. Steven Schiff, Chair  
Subcommittee on Basic Research  
Committee on Science  
US House of Representatives

March 2, 1995

Good morning, Mr. Chairman and Members of the Subcommittee. I'm Richard Herman, Chair of the Joint Policy Board for Mathematics, which represents three associations of mathematical scientists whose concerns encompass research, education, and applications. Thank you for this opportunity to talk to the subcommittee about the reauthorization of the National Science Foundation.

*Let me start by giving our strong endorsement to NSF's new strategic plan, NSF in a Changing World.* Most importantly, it reaffirms NSF's unique responsibility for maintaining the Nation's world leadership in science, mathematics, and engineering and achieving excellence in science, mathematics, engineering, and technology education. The Foundation plays a key role in ensuring the health and vitality of the mathematical sciences in particular. It provides virtually the only federal support for fundamental mathematical research--the study of measurement, forms, patterns, and change--to expand the intellectual frontiers throughout the mathematical sciences and advance our understanding of the universe, often in unpredictable ways. NSF also provides most of the federal funding that enables the mathematical community to work toward the improvement of mathematics education at all levels.

*We also support NSF's FY 1996 budget request.* Even with modest overall growth of three percent, the proposal would allow a 7.6 percent increase in Research and Related Activities. While we are concerned that the proposed one percent decrease in Education and Human Resources would adversely affect undergraduate programs (on which I will elaborate in a moment), we agree with NSF Director Neal Lane's assessment that, given the rapid growth in other EHR programs, there is now a need to evaluate them carefully and ensure they are on the right track.

It should also be noted that many education programs funded by the research directorates, especially those that connect education to research, would be expanded under the budget proposal. For example, the Division of Mathematical Sciences would emphasize Research Experiences for Undergraduates, postdoctoral fellowships, and regional institutes that bring researchers, schoolteachers, and students together to share in the inquiry and discovery processes that are at the heart of progress in mathematics.

I would like in the remainder of my testimony to address three policy issues that we ask the subcommittee to consider as it writes reauthorization legislation, starting with some thoughts on the nature of the relationship between discipline-oriented research essential to ensuring world leadership, and thematic programs designed to address specific national needs.

### **Research in Areas of National Need**

In the correspondence inviting me to testify today, the following question is posed: "Is the balance between curiosity-driven research and strategic research at NSF correct, and what criteria should be used to determine the proper allocation?" I'd like to suggest that the issue be looked at in terms of the two research goals adopted in NSF's strategic plan: maintaining world leadership (mentioned earlier) and promoting the discovery, integration, dissemination, and employment of new knowledge in service to society. It is important to recognize that these goals are tightly interrelated and do not necessarily correspond to a crisp division between curiosity-driven research and strategic research. Curiosity-driven research often leads to contributions toward meeting societal needs; moreover, strategic research, which is more properly labeled research in strategic areas, can enhance the preeminence of the research enterprise.

As a practical matter to facilitate service to society, some federal research activities are organized into thematic programs associated with areas that have been identified as priorities through the confluence of the political and scientific processes. It is appropriate for NSF to have a special responsibility for the fundamental research components of these programs. NSF is really in the best position to engage the academic community in the most promising basic research to address the scientific problems that arise in these and other areas of national need. There is a growing convergence among research driven by scientific opportunities and research likely to advance important areas, and both society and science benefit from NSF's ability to make connections between the two.

*We recommend that rather than seeking a balance between thematic and non-thematic programs, NSF be held accountable for how its aggregate effort is achieving its goals and addressing societal needs.* We are concerned that rigid guidelines for the allocation of the budget between thematic and non-thematic programs would compromise the agility of NSF and diminish the capacity of the research enterprise to respond to as yet unforeseen scientific opportunities and societal needs. The division of dollars in any given year is less important than ensuring that NSF's research portfolio is designed according to its potential to meet its goals and serve society over the long term.

An important corollary of this recommendation is that the proper allocation of funds between categorical and noncategorical programs is not necessarily the same for all disciplines. We are happy to note that the NSF Division of Mathematical Sciences is involved in all of the currently identified areas of national need, providing mathematical scientists with challenging opportunities to investigate the mathematical foundations of complex phenomena and processes associated with critical areas of science and technology. But the ongoing availability of the mathematical sciences as a broad and versatile resource for the nation would be jeopardized if all growth in NSF support for the field continues to come from thematic programs.

### **Undergraduate Education**

The second issue I would like to discuss is undergraduate education. I know that Members of the Subcommittee have expressed concerns about the quality of education at our universities. The mathematical community believes in the paramount importance of undergraduate education and has been working consistently to improve it. While NSF's Education and Human Resources programs have been growing rapidly in recent years, most of the new funding has been devoted to K-12 activities, and deservedly so. But we suggest that the NSF Division of Undergraduate Education (DUE) is underfunded relative to its importance to education reform at all levels. *We urge the subcommittee to encourage and expand the DUE curriculum development and faculty enhancement programs as the most effective way for NSF to help strengthen undergraduate education.*

For over a decade, the mathematical sciences community has been working to revitalize a key ingredient in undergraduate education: the calculus course. NSF's leadership and support for this effort have been absolutely crucial to its success. We simply could not have taken a comprehensive, systemic approach to reform without a concentrated NSF initiative in the area. Between 1988 and 1994, NSF provided \$3 million a year to fund about 10 major curriculum and text development projects (in the early years), dozens of smaller curriculum reform and faculty enhancement projects, and (in the later years) dozens of dissemination and large-scale implementation projects to adapt the new curricula and teaching methods for widespread use.

A recent assessment conducted by the Mathematical Association of America describes the overall success of calculus reform efforts and testifies to the essential role played by NSF. By 1994, materials developed with funds from the NSF calculus initiative were in use at over 800 colleges and universities as well as 300 high schools, and nearly one-third of all calculus enrollments were in reformed courses. Evaluations of these new courses show that students believe they are learning more, getting higher grades on standardized tests, and more frequently continuing their study of mathematics.

The movement to improve the teaching and learning of calculus is still fragile and requires support to sustain momentum. Moreover, the success of the program has prompted educators to identify other courses and disciplines where NSF's involvement could leverage significant change for the better. DUE is now supporting curriculum initiatives in introductory chemistry and interdisciplinary mathematics, for instance. So we strongly recommend that the division's budget be allowed to grow at least modestly, not decline as proposed, while calculus reform is still in the critical implementation phase and new efforts in other areas are just getting underway.

It should also be noted that strengthening undergraduate education is a prerequisite to true reform at the K-12 level, because prospective science and mathematics teachers learn subject content and are influenced by teaching styles in their undergraduate courses. It is therefore critical that the education we offer more properly captures the image of society.

### NSF and High Performance Computing

Finally, let me make a few comments on NSF's role in the High Performance Computing and Communications (HPCC) program. I would like to emphasize for the subcommittee that high performance computing technologies are revolutionizing research in many areas of basic science, mathematics, and engineering. This potential was actually identified in the early 1980s, long before the federal government established a multiagency program in this area. Since that time, NSF has taken the lead in providing academic researchers with access to advanced computing technologies and investing in the mathematical and computational research that enables their use in solving highly complex scientific problems. NSF continues to help the research community through the cost and technical barriers that prevent bringing the full advantages of HPCC technologies to bear on key problems on the edges of the intellectual frontier. *We urge the subcommittee to champion NSF's involvement in high performance computing as an essential component of the Nation's basic research infrastructure.*

Many of NSF's research divisions support work characterized as part of the HPCC program. In the mathematical sciences, basic research carried out under the HPCC banner has led and continues to lead to new mathematical methods, algorithms, and conceptual models motivated by the multitude of issues that arise in the development and use of more powerful and interconnected computing environments. Making use of these environments also requires the invention of sophisticated software tools by interdisciplinary teams of mathematical, computational, physical and biological scientists and engineers.

These interactions are stimulating new creativity and progress in many fields as researchers chip away at the so-called "Grand Challenge" problems, like atmosphere and ocean modeling, molecular design, and improved understanding of physiological processes. NSF is truly inventing the future of basic research, when computational and numerical "laboratories" are able to replace expensive physical facilities and time-consuming processes, much as mathematical models simulate wind tunnels so that aircraft designs can be tested before prototypes are built.

In conclusion, Mr. Chairman, let me thank you and the members of your subcommittee for the supportive comments you've made on behalf of the National Science Foundation. I hope you will agree that it is a valuable national resource for meeting our research and education needs in a comprehensive and coordinated fashion--the advancement of knowledge across the spectrum of science and the development of human resources from students to educators and researchers. NSF has also been working diligently to ensure that its programs meet the highest standards of quality and contribute to the objectives identified by Congress and the Administration. The agency is clearly poised to lead the mathematics, science, and engineering enterprise toward an ever more active role in securing the Nation's health and prosperity.

Thank you very much for your consideration of my remarks. I would be pleased to answer any questions you might have.

Mr. SCHIFF. Thank you, Dr. Herman.  
Dr. Schmitt?

**STATEMENT OF DR. ROLAND SCHMITT, CLIFTON PARK, NEW YORK; CHAIRMAN OF THE AMERICAN INSTITUTE OF PHYSICS; REPRESENTING THE EXECUTIVE COMMITTEE, COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS; [FORMER CHAIRMAN, NATIONAL SCIENCE BOARD]**

Dr. SCHMITT. Thank you, Mr. Chairman, Mr. Geren, Members of the Subcommittee:

It is a pleasure to be here. Although I am here on behalf of the Council of Scientific Society Presidents, and as Chairman of the American Institute of Physics, I have to tell you the views I am expressing are my own. They are based on my 37 years of experience in General Electric in industrial research, my 5 years as a university president in a technological university, and my 12 years on the National Science Board, 4 years as Chairman. I find it hard to overcome all the accumulated prejudices of those years.

[Laughter.]

Dr. SCHMITT. What I have to tell you is that NSF has played a crucial role in our Nation, I think, because of the fact that it has held to some core values of the scientific enterprise while still responding to the challenges of the nation.

The budget proposal before you, in my view, balances the dedication to good science with attention to the key issues—to many key issues of national priority.

These goals—knowledge and discovery on the one hand, and usefulness on the other, usefulness and public good—are not at loggerheads as they are so often represented. In fact, I believe that each can enrich and energize the other.

I am impatient with distinctions between “basic research,” “applied research,” “curiosity-driven” and “strategic research.”

I directed an industrial laboratory whose scientists won Nobel prizes, were elected to the prestigious academies of the U.S. and around the world, and concurrently generated multi-billion dollar businesses for General Electric Company and solved commercial problems.

I was president of a university which embraced interactions with industry for two reasons. It helped us in the education of our students; and it provided us with stimulus to understand new problems that fundamental science should address.

So I want to answer the first question that you have asked—namely, the balance between curiosity-driven and strategic research at NSF—based on that background of experience.

In my view, it is largely a distinction without a difference. The research in strategic areas can be investigator-initiated, and at NSF should be investigator-initiated, just as well as those in other areas.

Curiosity and strategy are not at odds with each other. They come together very well. Let me give you one of my favorite examples of that:

It has to do with Irving Langmuir, a scientist at General Electric Company, earlier this century. The Director of the Laboratory

handed him a blackened light bulb and said, Irving, we've got to find out why the light bulb blackens.

Langmuir was a scientist driven by curiosity. So he took that bulb back to his laboratory and, instead of changing the configuration of the filament, the size of the bulb, he started studying the fundamental physics and chemistry of what was going on inside that bulb.

The result was twofold:

He solved the problem, and he launched modern surface chemistry that won him a Nobel Prize.

So I believe that these two things are totally compatible with one another. So it is reasonable in my opinion to ask the National Science Foundation to devote a high fraction of its research to areas of already-known relevance to important national goals, provided that the support is targeted to good scientific ideas about those.

But I must also say, we do also need scientists to explore frontiers of knowledge that we do not yet see as especially relevant to specific national needs. So how do you balance these two?

In my view, you balance them by looking at merit. Merit is what should determine what NSF supports. The response NSF gets to its identification of strategic areas, the proposals it gets from scientists who have proposals in areas that have not yet been identified as strategic, ought all to be judged on a common basis of merit and let the ratio between those two fall where it may.

The next question you have asked is the balance between research and education. I have said in my written statement what my views are there and I will just summarize them quickly by saying that I think that it is reasonable to have a pause in the growth of the overall resources in that area, as Neal Lane is proposing this year. That program has grown very rapidly.

As many of you know, Congress has traditionally moved money out of research areas into education and grown that faster than NSF had proposed in the past. I think that that has not been an unreasonable thing to do. I don't mean that it has grown too rapidly, but it is at the moment when it is timely to pause and see how these programs have worked and reallocate some resources before you resume growth.

The third question is about academic research facilities. My own view there is that NSF should have a strong facilities program. I have held that view during my service on the National Science Board—not very effectively, however—and I was happy to see Congress's initiative last year, but I am disappointed to see the recisions in that program this year, frankly.

In my written testimony I identify the three basic objections that people have had to a strong facilities program and tried to answer them, and I would be happy to elaborate on that during the questions, if you like.

The last question is about under-funded areas: in a sense every area of science is underfunded. Science by its very nature tends to generate more questions, or at least as many questions as it does answers. That is the dynamic of it.

So, I think that in one sense, you can claim that virtually every area supported by NSF is underfunded because there are in fact

more good ideas out there, meritorious ideas, than NSF or other agencies have been able to fund.

So the proper answer to that question is that I don't really know of any area that is more underfunded than any other. I think that the balance that NSF has struck there is quite reasonable.

So in concluding, I want to make just a few more general remarks about the role and importance of NSF for the nation.

It is a small agency. Its research budget is only about three-and-a-third percent of the total Federal R&D expenditures. It is less than a fifth of the federal expenditures on basic research alone.

Surprisingly, it is only about 10 percent of total—total—academic R&D, and less than 1/5th of the federal support of academic R&D.

But I believe that the effect and the impact of NSF on the nation's strength is bigger, its genius, its talent, and its achievements in science extend far beyond its dollar contributions. In no small measure that is because the agency has learned to maintain the high quality of the research it supports while still responding to national priorities.

Congress has demonstrated its approval of this dedication to both quality and responsiveness by its strong support of the agency. It requires a high degree of foresight and faith to do this, because the practical payoff of forefront science may not always be in the short term.

We enjoy today in our nation the fruits of the investments in science that our predecessors made, and I believe that we owe no less to our heirs.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Schmitt follows.]

Remarks By  
Dr. Roland W. Schmitt  
Before The  
Subcommittee on Basic Research  
Committee on Science  
House of Representatives  
March 2, 1995

Chairman Schiff, Mr. Geren, members of the subcommittee, I appreciate the opportunity to testify before you today at this reauthorization hearing for the National Science Foundation. I am here representing the Council of Scientific Society Presidents, a consortium of 60 scientific societies and federations with a collective membership of 1.3 million. I am a member of that Council as Chairman of the Board of Governors of the American Institute of Physics. But, the views and perspectives I bring here today are most strongly based on my 37 years with General Electric in industrial research; my 5 years as President of Rensselaer Polytechnic Institute, a premier technological university, and my 12 years on the National Science Board, 4 years as chairman.

Throughout my service in these several positions, my view of the National Science Foundation has remained constant: it is the heart of the academic scientific enterprise in the U.S. The genius of its creation almost 50 years ago accounts in large measure for the scientific pre eminence of our nation today. NSF has played this crucial role in our nation because it has held to core values of the scientific enterprise while at the same time responding to the challenges of each era. The attachment to core values and the ability to change continues today and is reflected in the budget proposal before you. It balances dedication to good science - depending on the talents and intellect of first class scientists in choosing the paths to discovery and knowledge - while addressing key issues of national priority.



These goals - knowledge and discovery on the one hand, usefulness and public good on the other - are not at loggerheads as they are too often portrayed. In fact, each can enrich and energize the other. I am impatient with the distinctions between basic and applied research or between curiosity-driven and strategic research. I directed an industrial laboratory whose scientists won Nobel Prizes and were elected to the prestigious academies of the U.S. and other nations while concurrently launching a number of multi-billion dollar businesses for General Electric and solving many industrial problems. I was President of a university that embraced strong ties to industry because they strengthened our ability to teach our students and they helped us find challenging problems of fundamental research.

NSF today, as represented by its budget proposal, is synthesizing these synergistic aspects of scientific research in an exemplary manner. Neal Lane, the Director of NSF, is continuing to evolve and develop the basic concepts and policies of this synergy. During the past decade, beginning with a Republican Administration and a Democratic Congress and continuing to the present budget cycle, NSF has evolved tremendously in its strategies and programs for linking the nations scientific genius to its national goals.

Let me comment explicitly on some of the questions you have posed for this hearing. First, "Is the balance between curiosity-driven and strategic research at NSF correct, and what criteria should be used to determine the proper allocation?"

As you can tell from my prior remarks, I do not believe that curiosity and strategy are at odds with each other. They commingle very well. The real distinction is whether the area of curiosity is already known to be relevant to national needs or is not yet recognized to be. We need a high level of attention by scientists in areas where we already know there are issues to be addressed, problems to be solved, where we believe their curiosity will lead them to discoveries and knowledge that we already need. These areas often hold mysteries of nature and challenges of exploration as exciting to the scientific mind as any to be found.

One of my favorite stories is of Irving Langmuir, a scientist at General Electric's Corporate Laboratory earlier this century. GE

was having trouble with its light bulbs turning black too soon. The director of the lab asked Langmuir to see what he could do about this. Langmuir, being pre-eminently a scientist driven by curiosity started to study the chemical and physical phenomena going on in those bulbs. The result fulfilled the wildest dreams of science and of GE. Langmuir not only discovered how to solve the blackening problem but also launched modern surface science, an achievement that led to his winning the Nobel Prize in chemistry.

But, we also need scientists to explore frontiers of knowledge that we do not yet see as especially relevant to specific national needs. In fact, it is from such research that we often learn about new opportunities to improve the human condition, even, sometimes, what questions to ask, what issues to address.

Thus, I believe it is reasonable to ask the National Science Foundation to devote a high fraction of its research support to areas of already known relevance to important national goals provided that the support is targeted at good scientific ideas, motivated by curiosity in these relevant areas. What has come to be regarded as the "curiosity versus strategy" controversy is wrong-headed. The distinction that might be made is "known relevance", which is being labeled "strategic", versus "not-yet-recognized relevance", which is being labeled "curiosity-driven".

Thus the answer to the second part of your question becomes clear. The key criterion is simply this, We should devote as much of our research support to areas of known relevance to national goals as there are good scientific ideas for making discoveries and advancing fundamental knowledge in those areas. Obviously, how much this will be will depend on budgetary constraints and on how high our threshold of merit is for the ideas. The corollary is that the resources we should devote to the areas of unknown relevance is an amount sufficient to support scientific ideas of merit comparable to those being supported in the areas of known relevancy. The important point is that the threshold of merit should be equally high across all the areas of research supported by NSF. This is the feature that will determine the proper balance between "strategic" and "curiosity-driven" research. A large part of academic research is already in areas relevant to national interests - fields like Advanced Materials & Processing, Biotechnology, Civil Infrastructure

Systems, Environment & Global Change, High Performance Computing and Communications, and Manufacturing Science and Engineering. These fields are not only of economic and social importance; they are also rich with challenges to fundamental science. NSF should announce these fields of "strategic" importance, as it has done, insist on common standards of excellence across all of its grants, as it does, and let the ratios fall where they will.

Your next question, "Is the balance between research and education activities correct?" is more difficult to answer. Year after year for the past decade, Congress has almost always shifted funds in the administration's proposed budgets from research to education. I would have liked to see the education budgets of NSF grow a bit more slowly than they have for a simple reason. We need to find out which programs are successful, which not and it takes time to do that. I don't believe the programs have grown so fast as to have yet pushed us into non-productive programs, but the pause that Neal Lane is proposing this year is timely. I'm sure that the varying successes of the education programs will suggest some re-allocations of these funds, and in a subsequent year the Foundation will be better positioned to know how to productively resume growth in this area.

Your third question, "Should growth for the academic research facilities program be provided at the expense of research project support? What level of funding should be provided to the academic research facilities modernization program?" This is the one area where I am a bit disappointed in the proposed budget. I have, since my early days on the National Science Board, in the early 80s, been a proponent of a stronger facilities program. Thus, I was delighted with Congress' action last year in appropriating \$250M for this purpose and am disappointed in the rescission in the '95 budget and the proposed amount for the next budget. There have always been three arguments against appropriating significant amounts for a facilities budget. First, the problem is so big that any reasonable budget can only make a little dent in it. Second, it takes away from research funding. And third, facilities are too easily captured by "pork" vendors!

Let me address these one by one. To say that the problem is so big that we can't solve it all and thus shouldn't even start is a not a good argument. Every little bit will help and federal money for this

purpose helps attract other sources of funding. Most college campuses have research buildings in desperate need of repair and renovation. Unfortunately, private individuals don't like to give money to repair roofs and renovate plumbing. So these things get neglected. Research needs non-leaking roofs to work under and lab benches and hoods in good repair just as much as it needs chemicals and oscilloscopes and computers. Thus, to the second point above, I don't regard the provision of facilities to be "at the expense of research" at all; you can't do good research without facilities. The problem is compounded by the way academic research is administered on most campuses. Research money goes to the principal investigator, facilities money goes to the administration. Thus, the principal investigators see NSF money, which they regard as rightly theirs, going to administrators whom they think have lots of other sources of funds. There will always be tensions in this relationship, but the need is real, it's big, and we should start.

The apprehension that a facilities program shouldn't be started because it will become a pork barrel is ironic. Most of the academic pork of the last decade, a decade without any significant facilities program, has been for facilities. A good, well founded, merit reviewed facilities program ought to decrease the propensity to pork. This would especially argue for a strong program centered in the National Science Foundation, which has been able to remain remarkably free of pork. Thus, personally, I would like to see additional resources put into this program, although there may have to be a slower build up than that approved last year.

Your fourth question is a long one. "What fields of science and engineering that have significant technological promise or importance for public policy formation are not adequately funded by NSF? Should NSF reallocate funds from fields for which it provides only marginal support relative to other funding sources to higher priority areas that are now underfunded?" These are really two different questions and I'll answer them differently.

First, I'd like to caution against giving too much weight to claims of underfunding. In one sense, virtually every area of science is underfunded in that there are always more challenging problems around than we can afford to support. It is the very nature of the scientific enterprise to generate as many or more questions than it

does answers! The amount you allocate to a field for research, which is NSF's regime, has to be determined by the quality of the ideas of the people in the field. NSF has a good system for doing this. First, its clientele, academic scientists, is generally comprised of competent, productive people who are at the leading edge of their fields so the program managers, division heads and higher administrators of NSF are in contact with the best science in the world. It has an extensive peer review system. Further, it brings in eminent people to serve on advisory councils. Finally, it is answerable to the National Science Board. Therefore, NSF is pretty good at detecting what's happening at the leading edge of most sciences and of moving resources from area to area as circumstances change. The ideal, of course, is to have equality of underfunding across all fields! But, the short answer to the first part of this question is that I know of no fields that are underfunded significantly more than others.

The second part of your question pertains to fields that are primarily funded by other agencies and only marginally funded by NSF. Should NSF move out of these and put its money in areas where it is the principal supporter? The short answer is "No", for the following reason. In areas principally dependent on other agencies for support, NSF can still be an important factor. Mission agencies may hesitate to fund a novel idea of possible but questionable relevance to their mission while NSF can do so because part of its mission is, indeed, to support quality ideas of unknown relevance, as I've said earlier. Thus, NSF will, and should, continue to be seen as supporting some projects in fields that it does not dominate. Again, I think the processes in place at NSF ensures that such projects will be of high quality - comparable to those in areas where NSF support predominates.

Your last question is "Is NSF moving quickly enough to increase grant size and duration? Should NSF place more importance on investigators' track records in making research awards and give seasoned investigators longer awards?" I can't answer the first part of this question as I've been away from the National Science Board for almost a year and don't know the current status. The track record of seasoned investigators is already an important part of the evaluation of proposals. It is reasonable to give such investigators somewhat longer awards than novice awardees. It would be even better to further decrease the administrative effort and paperwork

needed to continue or renew investigations. The offset is that NSF needs to be bringing along the next generation of leading researchers. This balance, between the novice and the seasoned is a balance at least as important to NSF as that between strategy and curiosity. In both instances, I strongly believe that NSF has the processes and mechanisms in place to do a good job.

I would like to conclude with a few general remarks about the role and importance of NSF for our nation. It is a small agency. Its research budget is only about three and a third per cent of total federal R&D expenditures, is less than a fifth of federal expenditures on basic research alone, and, surprisingly, is only about ten percent of total academic R&D and less than a fifth of the federal support of academic R&D. (These are the research and related numbers; they do not include the education budget of NSF.) I believe that the effect and impact of NSF on the nation's strength, vigor, genius, talent, and achievements in science extend far beyond its dollar contributions. In no small measure, that is because the agency has learned to maintain the high quality of the research it supports while still responding to national priorities. Congress has demonstrated its approval of this dedication to both quality and responsiveness by its strong support of the agency. It requires a high degree of foresight and faith to do this because the practical payoff of forefront science may not always be in the short term. We enjoy today the fruits of the investment in science of our predecessors and we owe no less to our heirs. I know that this Congress is highly dedicated to the well-being of future generations and I would suggest that for those future generations the importance of investment in high quality science is on a par with deficit reduction. There is no better place in the federal establishment to make that investment than through NSF. Thank you for your attention to these views and for the time you devote to these important issues.

Mr. SCHIFF. Thank you very much, Dr. Schmitt.  
Mr. Sawyer?

**STATEMENT OF MR. JAMES E. SAWYER, CHIEF OPERATING OFFICER EMERITUS, GREINER ENGINEERING, INC., IRVING, TEXAS; CHAIRMAN, THE AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES, WASHINGTON, D.C.**

Mr. SAWYER. My friends call me Tom Sawyer, for some unknown reason, and there is a misprint in what you were given. I am Chairman of the American Association of Engineering Societies with about 800,000 members representing chemical, electrical, civil, and all disciplines of engineering.

I am Chief Operating Officer Emeritus of Greiner Engineering, and my company practices infrastructure engineering in most of the states represented on this Committee. Some of the new Members I'm not sure, but all of the ones that you initially introduced we practice in.

I am not a researcher. I am not an academic. And it is kind of an embarrassment to be with all these smart people here, but my business relies on the fundamental research developed and knowledge to serve my grandchildren.

My measure, my reason for being here, is I am concerned about the future of my grandchildren.

I would ask you to please reduce the federal deficit, and not get them any more in debt than they are. I ask you to do that, while not hurting investment in the technology that will make life better for my grandchildren.

I speak in behalf of the budget as it is presented without a whole lot of criticism of it. I think the program that results in this budget in the strategic areas and the curiosity-driven research, and the allocation is a model that our company would like to emulate to make its strategic decisions.

Where do we spend our capital?

I think it is a great example of unbiased, competitive allocation of resources to needs. I do believe that there is a reasonable balance between research and education. I have a slightly different reason from my associate here.

I think we are faced with a society or a republic, a United States that is becoming more and more technically illiterate. I find that schools have dissuaded my daughters from technology and careers in technology—inadvertently, no malice there—because the teachers are not technically literate.

Third grade school teachers have told my daughters that, well, they really shouldn't be engineers. That's not appropriate. Math is hard and science is difficult.

I think it is a serious situation when Barbie Dolls talk about math being hard—because it is fun, and it is the way we are going to make life habitable for my grandchildren.

So I encourage you to not deny those of us in science and technology an opportunity to interact with the education community.

Our Society, the American Association of Engineering Societies, is devoting about 25 percent of its budget to interaction between K through 12, not to improve engineers or recruit engineers, but

to make the community we practice in more technically literate so we can communicate better with them.

The educational community in the United States does not have that heritage to permit them to do this.

I would agree with Dr. Schmitt that the division between curiosity and strategic research is a very, very broad and fuzzy line and probably meaningless. The division between basic research and applied research is equally broad and fuzzy.

For example, my bridge engineers use technology developed in science and engineering, basic technology and fluid dynamics, to make our bridges safe from the aerodynamic failures that destroyed the Tacoma Narrows Bridge.

We use finite-element computer technology to design major structures, including the Houston Ship Channel Cable Stayed Bridge which is nearing completion that will be the world's largest when it opens.

We derive that from NSF measurements on the Chesapeake Bay Bridge in your State of Maryland, which my firm designed, by the way. This saves an incredible amount of resources, because we can design lighter, more elegant, more durable bridges. But this knowledge is based on curiosity-driven engineering basic research by the National Science Foundation.

It is contributing to our international competitiveness. My firm is designing one of the largest bridges in the world in Hong Kong. We have brought \$10 million back to the United States, and we are using NSF-derived finite element analysis technology. We are sending drawings to Hong Kong over communications technology developed in this country under NSF auspices.

We are doing drawings in Baltimore, Maryland, on a computer and printing them in Hong Kong. We can work all day and, while we are asleep, we are transmitting the drawings and they're getting them over there.

All of this is based on NSF-based fundamental basic research that we use, and I think it is very important.

I can say that I don't quite agree with Dr. Schmitt. It is nice to fund facilities, but what NSF funds are people and I would not feel badly if we have beat-up universities. I went to Georgia Tech and I can tell you it was a beat-up place, and I learned a lot.

[Laughter.]

Mr. SAWYER. It is probably still beat up, and the more elegant, sterile laboratories may not be as conducive to development of young people.

I think that the grants funded—I would encourage you not to worry, as Congress people, about increased grant duration and so forth, because I believe that NSF has done an excellent job with the leadership of people like Dr. Schmitt, and Eric Bloch, and others, of being faithful stewards of your dollars.

Some of the greatest earthquake research, which will make life better for you people in California, is done by a university and a research center that competitively took that away from such places as Georgia Tech, MIT, and the University of California at Berkeley, because they had what it took to take it away. It is a small university that has what it takes to win in the competitiveness of NSF.



There is only one change I would propose that I regard as very important, and I proposed this last year when I testified on behalf of the budget.

In 1985 you gave science and engineering equal stature. There is confusion in the public that engineers drive trains, and my field of civil engineering drive trains while drinking tea with an extended pinkie and so forth.

[Laughter.]

Mr. SAWYER. I would encourage you to change the name, whether this allocation or others, to the National Science and Engineering Foundation. That is descriptive of the business of the Foundation.

My firm had a cornball name, Systems Planning Corporation, for awhile. We changed it back to Greiner Engineering because that is what we do. I think the name of an institution should correspond to what it does, and I suggest that it be the National Science and Engineering Foundation.

I appreciate your inviting an old country boy civil engineer like me to testify here. I really have a firm commitment to the heritage of quality that is exemplified in the National Science Foundation, and I encourage you not to fix something that ain't broke.

Thank you, very much.

[The prepared statement of Mr. Sawyer follows.]



AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES

**Statement**  
**of**  
**James E. Sawyer**  
**on behalf of**  
**The Engineers' Public Policy Council of the**  
**American Association of Engineering Societies**  
**before the**  
**Subcommittee on Basic Research**  
**Committee on Science**  
**U.S. House of Representatives**  
**on the**  
**National Science Foundation Authorization**

**March 2, 1995**

Chairman Schiff and Members of the subcommittee:

On behalf of the Engineers' Public Policy Council (EPPC) of the American Association of Engineering Societies, I am pleased to have the opportunity to share our perspective on the authorization of programs at the National Science Foundation. AAES is a multidisciplinary organization dedicated to coordinating the collective efforts of over 800,000 members to advance the knowledge, understanding and practice of engineering.

Given that two-thirds of U.S. productivity growth since the Depression can be attributed to technological advances, it follows that our economic security will depend to a great extent on our ability to compete in high technology areas. We believe that a sustained, merit-based Federal investment in R&D is a core function of the Federal government critical to our nation's productivity and standard of living. We support efforts to strengthen coordination and the overall effectiveness of Federal R&D agencies to reduce unnecessary duplication and maximize return on taxpayer investment.

#### **NSF BUDGET IN CONTEXT**

Recognizing that persistent budget deficits have forced tight discretionary spending caps, each Federal agency - including NSF - should be judged against yardsticks such as effectively executing its core missions, program efficiency, interagency coordination, merit review, value added by the Federal government to the states and the private sector, and national impact. In our judgement, NSF measures up to each standard.

EPPC endorses the administration's FY 1996 request of \$3.36 billion for NSF as a responsible request in the current budget environment. While comprising only 4% of Federal R&D spending, NSF is a cornerstone of the Federal R&D enterprise because it is the only agency charged with the broad mission of supporting the entire spectrum of science and engineering. The Foundation accounts for nearly 50% of the Federal funding for non-medical basic research at academic institutions. Moreover, NSF is promoting excellence in science, engineering and math education at precollege and undergraduate levels.

The Foundation's unique role in strengthening our nation's underlying knowledge base fills a critical national need and complements work by industry, states and other agencies. NSF's peer reviewed, quality-based system for allocating funding has led to generally high marks for management and efficiency at the Foundation. While benefits are difficult to quantify, NSF-supported research formed the basis for successful developments such as lasers, DNA, fiber optics, CAT scanners, biotechnology, composite materials, superconducting materials, microelectronic devices, and developments in information theory. In addition, we expect that the current NSF-supported research programs will lead to a host of commercially important technologies that could lead to entire new industries.

We are, however, concerned by proposals to arbitrarily cap NSF's future growth below the rate of inflation. Failure to support a sustained national investment in R&D and education threatens to mortgage our nation's future. Knowledge plus engineering know-how, a skilled workforce, and entrepreneurial investment produce the new products and services that create jobs and sustain our standard of living. The implications of this equation are

straightforward. If as a nation we reduce or otherwise allow our commitment to research to gradually decline, we do so ultimately at the expense of our standard of living. Certainly, our national budget problems must be tackled, but not by eating our "seed corn;" otherwise our problems will only proliferate. Thus, we urge Congress not to set arbitrary limits on NSF's long-term growth in real dollar terms.

#### **IMPORTANCE OF NSF ENGINEERING RESEARCH**

While engineers share with scientists in creating knowledge, engineers integrate and disseminate a diverse array of scientific, mathematical, and other forms of knowledge and convert it into information that can be put to use. The term "engineering" is often associated with application oriented activities at one end of a broad continuum. Examples include product and process development, testing and commercialization.

The other end of this engineering continuum - basic engineering research - is less appreciated but, in fact, serves as the basis upon which application takes place. At this stage, the engineering researcher investigates the systems and processes of the human-made and natural world. It is important to appreciate that it is at the basic engineering research stage that the overwhelming majority of NSF's engineering activities are directed.

We endorse the Administration's budget request for engineering programs at NSF. We are particularly pleased with the budget requests for the Engineering Directorate and the Computer and Information Science and Engineering Directorate, both set to increase at about 7%. Given the importance of engineering research to our standard of living, we believe NSF should maintain strong funding for engineering activities throughout its research directorates. Engineering research supported by NSF makes vital contributions to our nation's well-being in the following areas:

**Maintaining a strong academic research and education base:** A strong undergraduate and graduate education system and academic research base are unique resources that have helped to improve our national competitiveness. NSF provides about 33% of the total Federal funding for engineering research at academic institutions. NSF's programs directly sustain or affect an estimated 200,000 people including senior researchers and professionals; post-doctorate, graduate, undergraduate students; and K-12 teachers and students.

**Educating a competitive work force:** In addition to developing new knowledge, NSF's support for engineering research helps train highly qualified engineering practitioners and educators, ensuring both an adequate supply of PhDs to fill professorships and a diverse and well-trained engineering and technical work force. Such a work force enables industry to accelerate technological innovation and to stay one step ahead in the increasingly competitive global economy. NSF's Engineering Directorate, for example, supports a variety of innovative research and education programs such as Engineering Education Coalitions, Graduate Research Traineeships, Research Experience for Undergraduates grants, Engineering Research Centers, and its GOALI program which helps faculty and students pursue cooperative research with industry.

**Multi-disciplinary research and partnerships:** NSF engineering research and related education programs are helping academia to recognize and adapt to current and future needs of industry where solving problems increasingly requires multi-disciplinary approaches and partnerships to leverage available resources and build upon collective strengths. NSF engineering programs help to break down disciplinary barriers in academia and, through its centers and other programs, are encouraging productive partnerships among universities, industry, states. For example, in 1994, the 18 Engineering Research Centers were involved in approximately 400 joint projects involving over 416 firms and industrial consortia.

**Developing knowledge to help meet national needs:** Most economists agree that long-term Federal investments in science and engineering yield high annual rates of return to society both in terms of economic growth and living standards. Industry is able to invest only about 5% of its R&D in basic research due to its high-risk, long-term nature, and depends increasingly on NSF for supporting basic research at academic institutions. Although NSF does not support applied research geared toward commercialization of products, NSF engineering research has found its way into any number of useful products and processes that are improving our quality of life and creating jobs. A few current examples:

-- **Bioengineering:** NSF-supported research into the synthesis of new materials of biological origin and living tissue equivalents are helping advance the quality of health care. Researchers at the University of Texas at Austin, for example, have demonstrated that by using special polymers, human nervous tissue can be regenerated outside of the body for use in research and implantation.

-- **Micromachines:** With NSF support, researchers at the University of California-Berkeley, have developed a working electric motor small enough to fit on a silicon microchip. Future applications are expected in medicine and in space exploration.

-- **Materials:** NSF support has enabled researchers at the University of Iowa to develop a machine that can detect weaknesses in metal structures without damaging the material. This technology has wide application in detecting metal fatigue, corrosion, or heat-inducing embrittlement in bridges, buildings, aircraft landing gear, and other objects subject to metal fatigue.

-- **Environmental Remediation:** With NSF support, researchers are experimenting with the use of electro-osmosis as a process for treating contaminated soil. This emerging technology should prove useful in dealing with hazardous waste remediation and treatment.

#### **BALANCING THE RESEARCH AGENDA**

One of the most valuable characteristics of NSF is its broad mission and flexible structure. We are pleased that NSF has expanded its efforts to pursue research in areas of national need, and we believe NSF has generally achieved an appropriate balance between curiosity-driven research and research in strategic areas of importance to the nation. However, given

the overlapping nature of curiosity-driven research and research in strategic areas, we caution against trying to determine a specific percentage balance of research funding. NSF devotes a significant and balanced portion of its portfolio to strategic areas, defined as fundamental research or education in areas broadly identified as a national need. Mr. Chairman, the misconception that research in strategic areas is applied research, or that fundamental research and research in areas of national need are mutually exclusive must be laid to rest. Research in strategic areas is fundamental in nature, and encourages researchers to consider their work in a larger context.

We emphasize the integrative nature of basic research and research in strategic areas. Basic research strengthens the overall knowledge base and holds the prospect for path-breaking discoveries whose outcome can not be predicted today, but may lead to new products and industries in the future. Basic research in areas strategic areas is an important part of the research mix because it provides rich opportunities for collaboration and knowledge transfer among government, industry and academia and brings many disciplines together to solve complex problems. Such cooperation can increase the potential for early application of the knowledge generated. Strategic areas should be flexible so that researchers can pursue creative ideas and quality research. And NSF should modify areas and reprogram funding when necessary to meet changing national needs.

Strategic areas at NSF are focused around national needs identified by an NSF planning process, including input from researchers, and coordinated with the National Science and Technology Council. NSF has identified and directs funding toward broad strategic areas such as education, biotechnology, advanced manufacturing, advanced materials, high performance computing, civil infrastructure, environmental technology, and global change - all of which are set to increase in FY 1996. This type of activity, supported strongly by the Engineering Directorate, should be encouraged.

#### **EDUCATION**

We believe NSF has demonstrated great leadership in improving engineering, math and science education. Although much attention appropriately has focused on precollege education, along with NSF's traditional support for graduate education, the Foundation also plays a key role in revitalizing undergraduate education, particularly in engineering.

Undergraduate education is especially important to industry because unlike many other technical disciplines, most engineers begin their professional careers directly after earning the baccalaureate degree. The increased demands in engineering practice for teamwork and leadership skills, and an understanding of the international context of engineering mean that the engineering curriculum cannot afford to stagnate. Furthermore, the changing demographics of the nation require us to find new ways of making engineering both interesting and relevant to all potential students -- particularly to women and under-represented minority and disabled students.

The NSF Engineering Directorate, for example, supports Engineering Education Coalitions (EEC) aimed at revolutionizing engineering education. These experimental consortia are

developing and disseminating coordinated innovations in curricula, use of technology in instruction, and student outreach. EECs also aim to improve the recruitment, retention, and graduation of more women and minorities. In addition, they also are providing engineering faculty with long-overdue recognition for innovations in teaching and learning. We applaud these initiatives and believe these and other undergraduate-focused programs should be strengthened.

Because U.S. engineers can begin relatively well-paid professional careers directly out of college, they tend to have limited incentives to continue on in graduate programs. While it is unclear to what extent our nation will face an overall shortage of PhD-educated engineers in the coming years, there is no doubt that we must attract the best U.S. engineering students into our graduate programs. A valuable incentive for U.S. students has been the NSF Graduate Fellowship Program, as well as the Graduate Traineeship Program initiated by Congress in FY 1992. We urge that the fellowship program be sustained and that the traineeship program become a long-term, fully-funded program.

#### **ACADEMIC RESEARCH INFRASTRUCTURE**

In recent years, Congress has attempted to increase funding through the NSF budget for academic facilities and instrumentation. This is an area of great need. It has been estimated that about \$10 billion will be needed to modernize the facilities and instrumentation at many of the nation's colleges and universities. The modest \$100 million FY 1996 request for this program in no way begins to address the need. Only a coordinated interagency effort could tackle this problem in a realistic manner. Such an effort requires leveraging from other agencies and the private-sector, a critical assessment of facilities, and competitive merit review.

However, an interagency proposal has not been forthcoming, and significant rescissions have been proposed in this area. Unless and until the Federal government is able to tackle this problem in a comprehensive manner, we believe NSF should remain focused on research and education, investing in human resources first, and facilities and equipment second. NSF should not be directed to fund facilities and equipment at the expense of research and education programs.

#### **BROADENING THE NAME OF THE FOUNDATION**

In 1985, Congress broadened the NSF Organic Act to provide a statutory emphasis on engineering research and education equal to that of science. Among the requests from the engineering profession at that time was a parallel change in the agency's name to reflect this parity. Unfortunately, the change was not included in the 1985 law. In the intervening years, engineering at NSF has grown in importance and visibility. To reflect that reality, we renew our request that the Foundation's name be changed. We recommend that Congress amend the NSF Organic Act to rename the agency "The National Science and Engineering Foundation" and its governing board the "National Science and Engineering Board."

The Foundation has long since validated the vision of Vannevar Bush in 1945 when he recommended to President Truman in his report, "Science -- the Endless Frontier," that the

federal government needed to accept major new responsibilities for "promoting the flow of new scientific knowledge and the development of scientific talent" through the nation's universities and research institutes. His vision is equally valid today.

A major change in the frontier has been the evolution of engineering from what it was pre-World War II to its current status. The five years preceding World War II saw an average of only 60 doctoral degrees awarded each year in engineering, compared to more than 6,000 now awarded annually. Changing the name of the National Science Foundation will recognize the significant growth of the engineering profession not only in size, but also in importance to America's education and research base and to the nation's continued technological and economic well-being.

#### **CLOSE**

Finally, we ask that Congress not authorize new programs without providing commensurate resources, and that you provide the greatest possible degree of flexibility to NSF in managing its resources. It is clear that priorities will need to be set to ensure an appropriate balance of funding for NSF research, education and facilities and programs. Research and education remain high priorities, but Congress should recognize that funding for NSF research also serves to promote NSF's educational goals.

Thank you very much Mr. Chairman for the opportunity to present our views. We look forward to working with the subcommittee to sustain a high level of support for NSF in the coming years.





1995

**AAES Member Societies**

American Academy of Environmental Engineers  
 American Indian Science & Engineering Society  
 American Institute of Chemical Engineers  
 American Institute of Mining, Metallurgical and Petroleum Engineers  
 American Institute of Plant Engineers  
 American Nuclear Society  
 American Society for Engineering Education  
 American Society of Agricultural Engineers  
 American Society of Civil Engineers  
 American Society of Mechanical Engineers  
 Institute of Electrical & Electronics Engineers  
 National Institute of Ceramic Engineers  
 National Society of Professional Engineers  
 Optical Society of America  
 Society of Fire Protection Engineers  
 Society of Hispanic Professional Engineers  
 Society of Women Engineers

**Advisor/Observer**

National Academy of Engineering

**AAES Associate Societies**

Association for International Practical Training  
 Federation of Materials Societies  
 INFORMS  
 National Action Council for Minorities in Engineering  
 NACE International  
 National Council of Examiners for Engineering and Surveying  
 Tau Beta Pi Association  
 The American Society for Nondestructive Testing, Inc.

**AAES Regional Societies**

District of Columbia Council of Engineering & Architectural Societies  
 Engineering Society of Detroit  
 Washington Society of Engineers

Mr. SCHIFF. Thank you very much, Mr. Sawyer.

We will now begin with Subcommittee questions. Since this is the only second hearing of this Subcommittee, I would like to briefly say what my policy is with respect to questions.

It is my intent to call on Members in the order in which they were here at the Subcommittee as of the time we banged the gavel. At that point, then I will go left and right on the basis of seniority from that point. But I think we don't want to—I remember being a freshman, which does not seem all that long ago, and maybe it was not—but I remember you show up at a Subcommittee hearing, you know, face washed and everything, and you are there alone, and then 27 senior people sat down between you and the chairperson and that was it. You were gone for the rest of the day.

I never thought that was quite fair, and now I have got the chance to do something about that.

I am also going, because we have a number of Subcommittee Members here, I am very pleased to say, I am going to observe the five-minute rule for Members with respect to questioning, including myself. I want to say that, after that, if someone is dying to ask a question that did not have a chance to, I will recognize Members for a brief second round.

So, beginning with my own five minutes, I want to start by saying:

Dr. Schmitt, when you made a reference that curiosity and I believe strategy are not that separable, if I understood you correctly, if we can substitute the words "basic science" and "applied research" for the words "curiosity" and "strategy," if I got your meaning in that direction, I would like you to clarify, but if I understood you correctly, I am in full agreement with you.

I think there are a number of Members of Congress who say there should be a brick wall between the government funding basic research but shouldn't fund applied science.

I do not find the difference so distinguishable. Am I close to what you meant?

Dr. SCHMITT. You are absolutely right on target. The point is that if you send someone down into a laboratory of a scientist doing work and ask them to judge whether it is basic or applied by just seeing the measurements they make, the calculations they do, and the thoughts they have, they cannot tell the difference most of the time.

Mr. SCHIFF. Well, I think that it is absolutely correct. I want to say, I think what the government needs to be focusing on in terms of its funding is: What are its priorities? In what areas does it wish to submit research? Rather than trying to invent what I regard as a somewhat imaginary wall between the two.

Dr. Wolpert, I believe, sir, you are representing the Social Science Associations? Is that right?

Dr. WOLPERT. Yes; that's right.

Mr. SCHIFF. Now I have to tell you that when I got my political science degree, my older brother the physicist said "political" science? That's blasphemy! How dare you use the word in that regard.

I cannot resist saying—and the staff is probably tired of hearing this—that this was in 1968. I remember saying very clearly, Wait

until I get to Congress and cut your R&D budget and we will see if you are such a smart aleck then—

[Laughter.]

Mr. SCHIFF. He now has to cross the street when we meet.

But let me turn to the serious point here. I made the observation in my opening statement that I have a concern about funding of hard science. I do understand the educational and social science goals of the NSF.

I want to again reiterate. I have no quarrel with them individually. I do understand that if you are not raising future scientists you have no science. But the hard science is funded by very, very few agencies. That is really my point.

So let me just go through the panel, and I will begin with you, Dr. Wolpert, since I mentioned you my name. Do you believe that we are not funding enough hard basic—or hard research. I don't want to use the word "basic" and get into that trap—but that we are not using these funds to fund enough research projects?

Would you change the percentages? And I am going to go through the panel beginning with you, Dr. Wolpert.

Dr. WOLPERT. I have been thinking a great deal about this question and have spent a good deal of time looking over their recent awards, National Science Foundation awards, in our areas.

I remain convinced that the present balance, which is about two-thirds for basic, hard studies and one-third for strategic areas, represents a very healthy balance.

So we are funding the good studies.

Now political science, I think since probably the time you were an undergraduate, has become a very rigorous, hard science. We are learning—

Mr. SCHIFF. I can confirm that. So can this whole panel, I think.

Dr. WOLPERT. Okay. But the challenge is now. What are the principles of the democratic process we have here that can be applied to the developing democracies in eastern Europe?

We are training hundreds of public officials from eastern European countries with principles that have come from hard analysis and political science, so I think it is a good balance.

Mr. SCHIFF. Dr. Herman?

Dr. HERMAN. Yes. Thank you, Mr. Chairman.

I would say what is being funded now is certainly superb research. There are many individuals who are not being funded. Many good programs or proposals are indeed not being funded. But again, I am very cautious about drawing this fine line between basic and applied.

I would rather see, if you will, as much money going toward the support of research as can possibly be gathered within the budget constraints, and allowing the NSF to fund the projects that it sees fit through the merit review process.

So I would prefer, rather than having directions being offered say to fund 60 percent here and 40 percent there, I do not think that that is the most productive way to get the research done.

I mean, if we go back and look at basic research which led to the semiconductor industry, which is now a mature industry, we see, for instance, support of basic physics and materials' research, if you will fundamental science, which positioned us well to respond when

the discovery of high-temperature ceramics was made in Switzerland. The U.S. scientific community responded quite well in taking a leading position now.

And this is, if you will, an immature industry, but I think it is a perfect example of where support of basic research has benefitted society and will continue to do so.

Mr. SCHIFF. My time has expired, but at the pending question of is our percentage of funding scientific research high enough, Dr. Schmitt, and then Mr. Sawyer, would you respond briefly, please?

Dr. SCHMITT. I would just repeat the fundamental criterion that NSF ought to always use. Namely, the merit of the ideas; the quality of the ideas.

It is difficult to compare those across fields, but nevertheless that is what they should be striving to do.

Mr. SCHIFF. Mr. Sawyer?

Mr. SAWYER. I tend to agree with Dr. Schmitt, and I believe that the NSF has done a superb job of this prioritization in conserving our resources.

I would say that I would always second-guess them, but I admire their process and I think it is an excellent process and it is meritoriously carried out.

Mr. SCHIFF. Thank you.

My time has expired. Did we lose Mr. Doggett?

All right, next then in arriving is Mr. Geren, the Ranking Member.

Mr. GEREN. Thank you, Mr. Chairman.

I was glad to hear Dr. Herman's comments about the improvements in the teaching of calculus that the NSF has supported. I just wish it had come along in time to help me.

[Laughter.]

Mr. GEREN. I had a calculus professor whose nickname was "Rice Paddy" because he sent more people to Vietnam than any Draft Board in America.

[Laughter.]

Mr. GEREN. We have a five-hour-and-three-quarter calculus course my freshman year, and I had a full head of hair at the beginning of the year, and—

[Laughter.]

Mr. GEREN. So I may go back and try it again. I went to that same school that Mr. Sawyer did and attended those same beat-up labs. I don't think they have changed much. I am not sure when you were there, but I was there at the beginning of 1970, and they were still very beat-up then and are probably still beat-up today. I use that to lead into my question.

An issue that, as I mentioned in my opening statement, this Subcommittee has been concerned about is: What is the appropriate level of investment in facilities?

Dr. Schmitt, you have expressed some concern about that issue. At some point, inadequate facilities do start compromising the mission of the science, and the quality of the science.

Additionally, it can also lead to the directing of NSF resources to certain schools, rather than other schools, and start those schools that are not able to upgrade down a slippery slope towards mediocrity or worse.

I just would—Dr. Schmitt, if you could talk about the facilities issue, then I would be glad to have comments from other members of the panel.

Dr. SCHMITT. Well, everyone recognizes that the need is very great. At universities, it is very difficult to get alumni to contribute to repairing leaky roofs. That is, in a nutshell, the problem.

The sources of funding for renovating buildings in which research is done are limited. The problem is great. The argument that the problem is so great that, you know, \$250 million or \$100 million, whatever it is, is not enough to start, is not a valid argument in my opinion.

We do need to start, somehow. Moreover, NSF funding can leverage other funding.

The other point to be made on this is that NSF will review those proposals from the point of view of merit, also. The fear that a program like that will be captured by the pork vendors, basically, is not a valid one, because if you look at what has happened, most of the pork going to universities in the past ten years has been facilities anyway.

I think quite the opposite argument is correct; that if you had a good, solid merit-based facilities program, it would permit one to try to solve this problem in a rational, merit-oriented way.

I have elaborated on those arguments in my written testimony, but basically that is my position.

Mr. GEREN. Dr. Herman?

Dr. HERMAN. Thank you for the opportunity to comment on this.

I suppose I will put on my chair as a dean rather than as chair of the Joint Policy Board for Mathematics, although I would count facilities as facilities and instrumentation, actually, which has been much the way the monies have been spent through the National Science Foundation.

I think this is actually an extremely important program. I would go back to the last Bromley Report that came out of PCAST which addressed this issue quite substantially, and I agree very much with what Dr. Schmitt has said.

I am less concerned about exactly where the money will go because of the merit review process. It may in fact encourage a differentiation mission among the so-called research universities, but I think this is, given what I see as the budget picture for the next decade, this is very much the, if you will, the only way universities, I think research universities, will survive is if they differentiate among themselves.

Mr. GEREN. Dr. Wolpert?

Dr. WOLPERT. I just want to repeat what I said earlier, that I would hope that funding for facilities not be provided at the expense of basic research. Both funding for facilities and basic research should be judged competitively in a merit review process.

Mr. GEREN. Thank you.

Mr. Sawyer, do you have anything?

Mr. SAWYER. I concur. I wasn't trying to put down the need for facilities at all, but I believe to second-guess the process where facilities compete in the National Science Foundation program, to improve the facilities funding at the expense of other programs is poor judgment.

I certainly agree that it would be nice to have improved facilities, but it is much easier for us alumni to contribute to facilities than it is to contribute to the development of knowledge, to faculty grants and so forth.

We have some people that will create a George Sowers Building, or something like that, on campus, that are kind of nervous about funding research on basic knowledge.

Mr. GEREN. That is a good point.

All right. Thank you, Mr. Chairman, my time is—

Dr. SCHMITT. I would like to rebut, if I might, just a minute. It is clear that Mr. Sawyer has never been a university president or a provost.

Mr. SAWYER. Absolutely.

[Laughter.]

Mr. SCHIFF. Thank you very much.

Mr. Ehlers?

Mr. EHLERS. Thank you, Mr. Chairman.

First a few comments, and then a question.

First of all, I want to assure our self-proclaimed "old country engineer"

[Laughter.]

Mr. EHLERS. —that Greiner is doing well not just because they changed their name back, but in our instance in Grand Rapids, Michigan, you came in and bought the premiere architectural engineering firm. I thought that was a very good move. They have continued to be successful.

Mr. SAWYER. Thank you.

Mr. EHLERS. I also want to reassure the panelists. I noticed several of them commented about the fact that "60 Minutes" had given an inaccurate portrayal. I want to reassure you that you do not have to tell this panel that. We experience that weekly.

[Laughter.]

Mr. EHLERS. So you are preaching to the choir with that comment.

On the issue of the difference between strategic and curiosity-driven, or investigator-initiated research, I wholeheartedly agree with Dr. Schmitt. I think that is a false distinction. I think it has done some damage to NSF.

I think that is a distinction, in fact, that was imposed politically more by the Senate than by the House, certainly. I think the key—and I appreciate your comments on that, Dr. Schmitt—the key is to fund good ideas. Good ideas generally will be related in some fashion of relevance to societal needs.

I think we should avoid making that distinction and stop worrying about the balance and just get rid of the idea of strategic research, and lump it all together.

I do want to comment also on the facilities issue. Something that always bothered me is that many academic institutions do not repair the roofs. My concern about starting a facilities program is that as soon as they depend on this, they won't fix the roofs hoping that at some time the Federal government is going to come along.

I experienced that at the state level as state legislator when the state legislature made the mistake of handing out money to all those institutions that had let their buildings get into disrepair.

So we had a special allocation of several—well, many millions of dollars to repair these buildings. The net result was that all the universities stopped repairing their buildings just assuming that when it got bad enough, the legislature would come and bail them out.

To me, maintenance is an ongoing annual expense of any institution and a well-run industrial lab or a university should take care of their facilities. I have a real problem with NSF getting into that business.

I would distinguish between "facilities" and "instrumentation." I don't expect universities necessarily to be able to provide the instrumentation. But the physical buildings, I think they have an obligation to amortize the investment and maintain depreciation accounts and continue to keep them in good repair—particularly if they are getting overhead from the research grants from their professors.

My one question from anyone on the panel who wishes to comment is:

It has been proposed—it's been discussed many times over the years—but there is some flesh to the proposal now that one good way for us to fund research in so-called strategic or applied areas other than—rather than doing what we are doing now, is simply giving a very substantial tax credit to industries which want to provide research grants to universities for research related to the interest of the industry.

By "substantial," I mean perhaps a 75 to 90 percent tax credit. Obviously that is big money for the Federal Government, but I would be interested in your comments on that and whether or not you think that might be a good way of getting at some of the concerns of society.

Would that be an effective way of funding research in this Nation?

Mr. SAWYER. It occurs to me, as Tom Sawyer the old country boy not as a spokesman for my fellows in the American Association of Engineering Societies, that the utilization of tax policy to promote programs in the interest of government is not a good thing.

I have seen you encourage my company to do a variety of things so that half of the management of Greiner now has to do with what are the tax implications.

I think that is not a good way to run a business, because you keep changing the tax implications as a Congress. So I suggest that—again, I think the program in the National Science Foundation is superbly run, planned, and managed, and I would hate for you to try to do things with tax policy that interferes with the way we do technology.

But that is not the position of the American Association of Engineering Societies. That is my position as a business person.

Dr. SCHMITT. The issue of the R&D tax credit, both with respect to industry's own R&D and with respect to the R&D they sponsor, of course as you are well aware, has been an issue for years, and Congress has time and again extended it for a year, or a year and a half, and you always do that because, when you look at the financial implications, you want to save money, and it is easier to save money in the outyears than the near-years, basically.

The real problem there has been the on-and-off nature of it. If tax credits, both the one you mentioned and the R&D tax credit for industry, could be made permanent, the studies I believe have all indicated they would have a substantial impact on R&D expenditures.

So the theory is good. The practice has not been.

Mr. EHLERS. Could I—

Mr. SCHIFF. The gentleman's time has expired. As you have heard, we have a vote. We have one more Member of the Subcommittee who was here when the gavel banged who I believe we have time to recognize for five minutes, and I will do so.

Ms. Lofgren?

Ms. LOFGREN. I am not sure I will take the full five minutes. I was interested, Dr. Wolpert, in your testimony. I think oftentimes it is hard to get listened to in the social sciences because it is one of those areas where everybody thinks they know what is going on and are less willing to look at solid research.

But I was very interested in the new efforts to understand and prevent violence. I think that is an area where the country really needs some basic research that is sound and solid to guide us as we move forward on what is a terrible societal problem.

Which leads me to another question. Having worked in Corrections and other areas for a number of years, I think the area of research in the social sciences is different in terms of distribution, as well. If you are in physics and you come up with something, you know which journal to print it in and every person who is interested in physics in the whole world has access.

Yet, there is not a network in the social sciences, and especially among practitioners, to utilize what is learned.

Do you have any thoughts on what efforts we should make in that area?

Dr. WOLPERT. You raise a very important issue. In fact, as you know, even though we have had a multiplication or a proliferation of the number of journals, there very frequently are not good opportunities for researchers to talk directly with practitioners.

In a number of areas we are attempting to overcome that issue by sponsoring joint meetings in which there is a panel, and in which the panel of practitioners presents questions to the researchers.

These meetings have been among the best attended sessions of all. So we need better communications. I don't know whether NSF is necessarily the best agency to be involved in that.

It has provided a great deal of pressure on researchers recently, and I think this has been very helpful, to spell out the further implications of their research. That is, not simply leaving it in purely basic or theoretical terms, but to spell out its potential implications.

I would like to refer your question to the staff of the SBE section of NSF to see whether they have some—

Ms. LOFGREN. I would be very interested in that.

Dr. WOLPERT. So you will hear from them.

[The material referred to follows:]



**Dissemination of Fundamental Research Findings to the Practitioner Community  
National Consortium for Research on Violence and other Focused Research Projects  
Directorate for Social, Behavioral and Economic Sciences (SBE)  
National Science Foundation**

Effective dissemination of fundamental research findings to policy makers and the practitioner community is an important goal for the planned National Consortium for Research on Violence. The program solicitation requires that proposals address the potential applications of research findings, and how fundamental knowledge will be transferred to policy makers, practitioners, state and local agencies and community-based organizations. In addition, the National Institute of Justice will provide \$200,000 to the research consortium to support communication and dissemination activities that target the practitioner community and the general public.

The model for the dissemination of findings from the research grows out of SBE's past experience with other research centers, such as the Center for Research in Cognitive Science at the University of Pennsylvania. That Center has tested theories about how humans acquire, store and retrieve knowledge through a partnership with the public school system in Philadelphia. Undergraduate and graduate students associated with the Center provide extensive mentoring to students in K-8 in mathematical reasoning, and in the process collect data that is later analyzed to test theory. This creates a continual exchange between research and application.

Ms. LOFGREN. The second question I have, really for all the panelists. In primarily what is called the hard sciences, I note that we are—although there are not tremendous cuts being proposed in this area—I am concerned that as a Nation we are not spending enough on basic research.

I am wondering if you can compare what we are spending to say what Japan is spending, or our global competitors, and give us any guidance on what that will mean for our economy?

Dr. SCHMITT. Yes, I can comment on that.

In total, R&D are a fraction of GNP, our expenditures are comparable. In civilian R&D, they are less. We are spending somewhere a little under 2 percent of GNP on civilian commercial R&D, whereas Japan I think, if I remember correctly, is around 3.

So that is kind of the comparison. So the question always is. How much commercial spinoff do we get from the defense stuff? No one has really answered that question well, yet.

Ms. LOFGREN. Finally, I was brand-new to this Committee and to the Congress itself, but in looking through the Science and Engineering Education Section, I was caught by the reduction in precollege programs. I know we focus on graduate education and undergraduate education. That is important. But if we do not have students well prepared to be successful, then ultimately we will not get to where we need to be.

I am wondering if you have comments or whether we should make an effort to change that trend line; or whether you think I am right to be concerned?

Dr. HERMAN. Well, I think you are right to bring this up. This is probably why Congress has been concerned with this over a number of years.

I think the position that Dr. Lane has taken is indeed the correct one; that much activity has taken place in this direction, and that it is time to have an assessment.

I think, even though Dr. Williams, who is an assistant director of education and human resources, has on various occasions proposed this, I guess my concern was that one of the principal ways in which universities can contribute to this effort is through the education of the next generation. So I have voiced particular concern over what goes on through education at universities.

The Division of Undergraduate Education is what I referenced. And in particular, educating the next generation of teachers, which is your point.

Mr. SCHIFF. The lady's time has expired. I assume you have all been through this before with us. We will be in recess for this vote and we will return as quickly as possible.

Thank you for your patience.

[Recess.]

Mr. SCHIFF. I want to thank you all for your patience. We do not know when we schedule these kinds of hearings when those bells and buzzers will go off, so we do the best we can.

I would like to note for the record that Dr. Schmitt is no longer sitting with the panel. He had an airplane to catch, and I released him from the Subcommittee with our thanks for the testimony that he did have time to provide.

We have also now heard from all the Subcommittee Members who were here when we began the hearing. I am now going to recognize Members on the basis of seniority on the Subcommittee.

Next would be the former ranking member of this Subcommittee, Mr. Boehlert.

Mr. BOEHLERT. Thank you, Mr. Chairman, but you did not have to remind everyone that I was not here when the hearing started.

[Laughter.]

Mr. SCHIFF. I wanted to say for the record you were right outside the door. I saw you.

Mr. BOEHLERT. I am sorry Dr. Schmitt left because he is a dear friend, and I was going to ask him, he said that every area of science is underfunded. That surprised me when he said that. I was going to ask him what he thought the appropriate level of funding would be.

But the thing that I am concerned about, and several references have been made to this, and I have not seen it and I have asked CBS for a copy, I am not sure that I disagree with the basic thrust of that "60 Minutes" program.

I am deeply concerned about the trends in undergraduate education and, quite frankly, I think too many of our best and brightest are spending too much time chasing research grant dollars and not in the classroom.

Some of them are chagrined when they are going to get a six-hour course load, and that concerns me.

Which leads me to the question. I would like all the panelists to ponder this, if you will:

How can we more effectively use research grants to promote undergraduate education?

Dr. Wolpert?

Dr. WOLPERT. Perhaps I would like to start. I suppose I could try to do it anecdotally.

NSF at an earlier stage of my career was very helpful. It sponsored teaching symposia, retreats, in which faculty members could go off and talk about education—primarily science education and primarily education for undergraduates. Those were very helpful. Those programs still continue.

That is, I am not denying that there are not problems, but the separation between what makes a good researcher and what makes a good teacher, that is a distinction that was artificially exaggerated on that broadcast.

I remain convinced that it is impossible to remain as a good teacher without substantial involvement in a continuing learning process, whether we call it "research" or whatever. So it is not that the system cannot be improved, but the notion that undergraduate students are not having an opportunity to be involved in science projects, science research I suspect is overdrawn. If so, we need some real good data. We need some good, hard analysis on that question.

Mr. BOEHLERT. Well I have not had the benefit of seeing it. I don't know if you did, Mr. Chairman? Did you?

Mr. SCHIFF. The "60 Minutes" program?

Mr. BOEHLERT. Yes.

Mr. SCHIFF. I did see it, and I want to say that I don't have the expertise to know how accurate it is, but the idea of "publish or perish" I have heard for decades as presented in that program. It is nothing new that I had not heard before.

Mr. BOEHLERT. Well, I am anxious to see it. I have ordered a copy of it, and a transcript.

Well, Dr. Herman?

Dr. HERMAN. If I might pursue your question, Congressman Boehlert, I think you are very right to be concerned about the issue, but frankly as a mathematician and as a dean, I do not see it at all in the way that the program portrayed it.

Mr. BOEHLERT. That does not surprise me.

[Laughter.]

Dr. HERMAN. All right. Thank you. I have to play my role.

No, I actually see, especially at Maryland and other institutions with which I have been associated, that most everyone is in the classroom, including the front-line researchers, and that the use of teaching assistants is an extremely valuable way to continue education.

Mr. BOEHLERT. I don't deny that. But substituting teaching assistants for the talented and experienced faculty that are busy pursuing research grants is not the way to do it.

Dr. HERMAN. You are certainly correct, sir. What I meant was, they are used in an ancillary way to increase the educational involvement of the university—educational contact of the students and the university.

At Maryland, for instance, we now have gone to teaching calculus in a very personal way, highly interactive, where students now are exposed to the calculus seven hours a week, three hours with an instructor and four additional hours with a teaching assistant.

These teaching assistants are the senior ones who are very carefully trained.

Mr. BOEHLERT. You know, it is apocryphal, and I know it, but I once heard a story that a student graduated from a state university after four years without ever having direct contact with a full professor. That is scary.

Dr. HERMAN. That is scary. I mean, I have not seen that, but I certainly cannot deny that it occurred.

Mr. BOEHLERT. Mr. Sawyer, would you care to comment on that?

Mr. SAWYER. Yes. I would suggest that "60 Minutes" is not where I go for how Congress acts, and I certainly would not go there for how universities act.

I am teaching a class tomorrow morning, as a practitioner going into the classroom, and I have found that there are full professors who are lousy teachers and poor researchers and have not learned anything since they got their doctorate. That is true in my company, unfortunately. We have some people that have not grown and progressed.

I would tell you that I believe that is the exception. I go into classrooms all over the country from time to time as a practitioner to explain what you are going to do when you get your degree, and I find there are biases against this, as there are biases against tenure.

I have concern about tenure, in that it tends to—and I am not for removing tenure—but it does permit someone to quit growing as soon as they get it. I think that is much more dangerous than what “60 Minutes” brought forward.

I find that most researchers at the universities where I go in the field of engineering—and that is where I practice—are good teachers, feed off of the students, learn from their students, and the students learn from them.

I will tell you that I go into the classroom because I learned from the students. It is not just for their benefit. So I would suggest that that is an obvious area of concern.

I think NSF is concerned about it, as well. The people I have talked to in the universities and at NSF in civil engineering, my field, are concerned about the over-emphasis on “publish or perish.” But I am more concerned about people that have attained rank and have quit learning and quit working.

So I think they are equally dangerous, and to criticize one as opposed to the other, I think the people that quit learning as soon as they get tenure are far more dangerous than the publish or perish—

Mr. BOEHLERT. I agree. And I know my time is up, and I hope we can pursue this a little bit further, but it concerns me greatly. Dr. Schmitt said we need scientists to explore the frontiers of knowledge, and boy do I agree with that.

But where are we going to get them, if we do not do a better job in the whole educational process? I am talking about preschool right up through graduate work. I do not think we are doing nearly as well as we should in K through 12.

I am not overly encouraged by what I see in the undergraduate education field, because I think the emphasis is too much in one direction. I think, quite frankly, from that side, me protest too much about “60 Minutes,” the presentation, but I will hold out further judgment until I have the advantage of the transcript and full viewing.

But let's work together and try to recognize that this is a problem. Maybe it is imagined. Maybe it is just potential. I happen to think it is very real, and I think we have got to deal with it in a more forthright manner.

So, Mr. Chairman, I thank you and yield back the balance of my time.

Mr. SCHIFF. I just wanted to say that, as the Ranking Member of the Subcommittee from the last Congress, I appreciate your being here and the contribution of your expertise—

Mr. BOEHLERT. Thank you.

Mr. SCHIFF. —to the Subcommittee and this Congress.

Ms. Rivers has passed. Therefore, I would like to recognize Mr. Doyle.

Mr. DOYLE. Thank you, Mr. Chairman. I have no questions at this time.

Mr. SCHIFF. I would like to recognize Mrs. Morella.

Mrs. MORELLA. Thank you, Mr. Chairman.

I did not hear the beginning of Congressman Boehlert's statement, but for somebody who taught at a community college, I do

know that there is some merit in the "60 Minutes" concept. It is just too bad everybody is judged by that very short segment.

I am also interested in the fact that you, Dr. Wolpert, have worked in the area of domestic violence, criminal justice, and the behavioral sciences.

In terms of engineering, I have already heard about that possibility in changing the name. I am reminded of when the name for Bureau of Standards was changed when many of us were here, and the idea was to call it "The National Institute of Technology and Standards" until someone said, hey, that acronym would be NITS—

[Laughter.]

Mrs. MORELLA.: —and we didn't really want to have NITS as an acronym.

But I think it is very provocative when you talk about the cadre that we may need in terms of buildings and keeping them in good repair, I think there is such promise in training people in elevator repair, escalator repair, and roofing repair.

You just remember I said that when you go along and find out that you've got elevators that need repair, and escalators, and all.

But I am interested in two points.

The concept that was made about women and minorities and what is being done to encourage them in K through 12, also undergraduate. I am always curious about when they go into the work world then the kind of chilling effect that they have, which then pulls them away from it even if you have been able to sustain from the Barbie who doesn't like math, you know, and on into college, and then into the work world.

Rita Colwell is a great example of someone who is a great role model.

That, and then the concept of priorities for research. If you have any priorities you may want to suggest in terms of research.

So with that kind of double-edged question, I would like to ask you if you would like to comment.

Dr. WOLPERT. Perhaps I could start.

On the issue of women and minorities, my judgment is in observing the role of NSF is that they are doing a good job, and they have been very effective both in terms of new programs as well as in committee assignments, advisory committee assignments, as well as in staffing patterns.

So there needs to be further—even among the social sciences there is considerable variation among the research community in representation of women and minorities, more in fields like sociology, fewer in fields like economics.

But efforts through the Science Resources Data, we are able to monitor this, watch this, and I am hoping that support for these specialized programs can continue in the future. So that is terribly important.

In terms of priorities, especially for new strategic areas or for basic science, the experience that all of us have had who worked on advisory committees at NSF is that the internal process is working well.

As a result of having so many oversight committees and advisory committees, there is a good deal of communication between the

agency and the outside research community and other interested people.

It is working well. That is, that system by which ideas incubate, get tested and reviewed, is okay. It is not broken.

Mrs. MORELLA. Dean Herman?

Dr. HERMAN. Thank you for the opportunity to comment on these questions.

So taking things in the same order, if you will, the access or, if you will, the way the success of women and minorities at the undergraduate level, at universities, I think has been greatly increased due to the prodding of NSF.

I think what has happened is there have been great changes in not only the way we teach, but what we teach. In particular, the bringing of technology into the classroom. I think all of these have resulted—and there are numerous programs to cite.

Urie Treisman's work has had rather profound effects on increasing the success rates for women and minorities. So I think all of this is to the better and relates very much to the testimony I gave.

To take Dr. Wolpert's point, I think ultimately the merit-based review of research is what determines the best proposals to be funded. And this internal prioritization, if you will, is not entirely an internal one due to the many advisory committees, but I think there are some issues where Congress, if you will, has opened an appropriate concern for say in health care and in the way universities might contribute to that through the many examples that the National Information Infrastructure could provide.

For instance, in emergency medical care.

So there are areas like that which create an overlay of priorities, but once that has been said, then the NSF should be, if you will, free to address that situation within its usual merit-based review process.

Mr. SCHIFF. The time of the gentlelady has expired.

Ms. Jackson Lee.

Mrs. MORELLA. We'll catch Mr. Sawyer the next time.

Ms. JACKSON LEE. Thank you, Mr. Chairman.

Mr. SCHIFF. I'm sorry, Ms. Jackson Lee, could I ask you to suspend one second? I did not mean to interrupt.

Mr. Sawyer, if the lady would defer for one more second, from Texas, I did not mean to interrupt a witness who might want to add to that.

Mr. Sawyer, please?

Mr. SAWYER. That subject is dear to my heart, I appreciate your patience in letting me speak. I have two daughters. I have a granddaughter in Maryland that I do not want to see denied the opportunity to be a practicing engineer and technologist, but our K through 12 is biased against women in technology, as I said.

In participating with the National Science Foundation in its K through 12 initiatives, we are bringing that aspect I think into the standards that are being set. That is the key reason for the EES initiative in engineering education, the K through 12 initiative.

We are in a table, in my field of civil engineering, of about 15 percent. That is unsuitable. We are losing too many great minds, of all places, to the legal profession where they impede our technological advancement.

[Laughter.]

Mr. SAWYER. They are the natural enemies of technological innovation. So it is a key part of the NSF program in the K through 12 to, in my view anyway, to provide opportunities for women to become technically literate and therefore able to participate in technology.

I will say that one of the great leaders in EES is a past president of the Institute of Electrical Engineers, our largest organization, and she is very active in this endeavor. Martha is probably one of the premiere electrical engineers in history.

Also, you mentioned NIST. The Director there is a very competent electrical engineer lady. So we are making progress, and I would encourage us to continue to permit and encourage NSF to encourage these minds to be available to my grandchildren, because I think it will improve—this is not an equal opportunity thing; it is a commitment that I personally have to not lose great minds that can add to the technology that will handle our burgeoning population and the pressures they will put on the environment, and on service and technology.

So I think that NSF has that as part of their standards-setting and their programmatic issues in K through 12, and we are going to encourage it to get stronger and better as a profession.

Mrs. MORELLA. Thank you, Mr. Sawyer.

Thank you, Mr. Chairman.

Mr. SCHIFF. Thank you.

Mr. Ehlers has returned, but I began to recognize Ms. Jackson Lee, so I believe it appropriate to continue that.

Ms. Jackson Lee?

Ms. JACKSON LEE. Thank you very much, Mr. Chairman, and good morning to each and every one of you.

I have a series of questions. I will try to make them relatively brief and give as much time to your brief comments, if I might.

Let me just initially state that I am certainly empathetic with leaking roofs and other types of needs. I happen to have a spouse in academia and understand that, but let me say that I lean toward getting the dollars to the consumer and would hope that all of the well-intentioned alumni with all of their bright colors of their university would be kind enough to participate in the capital improvement program.

So I would be more than happy to send that tune out across the nation, and maybe participate as well, in the institution that I graduated from.

I am glad that the Chairman has given dignity to my science degree in political science. It has allowed me now to stand a little bit taller.

If I might ask first Dr. Herman if—and I know this is hard to be brief—but in any event, how our trend is going in basic research that is sponsored by the National Science Foundation as relates to our national needs?

Are we on target for some of the national scientific needs, or national needs of progress in this country, consumer needs, and that our science is in sync, if you will, with the basic needs of this country, or its need to be competitive internationally?



Dr. HERMAN. I think the answer is very much "yes," Congresswoman Lee, both in the way basic research, if you will, has contributed to the long-term societal needs both here and abroad, and in the way certain activities have yielded short-term results.

I think the example I gave earlier was one which related to physics and the success of the support of basic research helping to promulgate what will be a superconducting industry, very much like the semiconductors' work.

I think the example Dr. Wolpert gave of basic mathematical research affecting for instance the auction process which took place in helping to, shall we say, enhance the federal coffers.

So I am very happy with the yield of scientific, basic scientific research, both in terms of building a knowledge base and in terms of yielding direct societal benefits.

Ms. JACKSON LEE. You either apparently have read my mind or we have had an earlier discussion. I want to follow up on that superconductivity and try to—it is an expensive research, as I understand it, but ultimately, if we look to where it would translate in the business world, I see great, great opportunities.

So you would argue vigorously—am I hearing you correctly—for high-cost research and, for example, super-conductivity possibly being that physical structure, or the continuation of that research?

How would you balance that?

Dr. HERMAN. Well, I guess I am not too sure what you mean by "high cost," say, as opposed to the superconducting supercollider. I don't want to get into the middle of that debate.

Ms. JACKSON LEE. Well, if research costs—we had to maintain it—

Dr. HERMAN. But I think we have to decide what it is we want, through various processes, and then find a way to fund it.

So, if you will, a certain prioritization has to take place. I used superconductivity as an example of the research direction where I think there has been and will continue to be considerable payoff, even though, or especially because of the considerable investment on the part of the nation.

Ms. JACKSON LEE. I appreciate that.

Mister—I see that I have lost the other gentleman, but Dr. Wolpert, I want to continue on the superconductivity research and this working together with universities.

Is that the kind of research that appropriately or effectively can be housed in universities?

Dr. WOLPERT. Well, it can be. I first want to say that, you know, I am very glad that you identified yourself as a political scientist because you probably took offense, as I did, about the distinction between the so-called "hard sciences" as opposed to—

[Laughter.]

Dr. WOLPERT. I think our sciences are probably as difficult as any of the others.

Ms. JACKSON LEE. And that is why I asked you the question, because you are in a different science.

Dr. WOLPERT. Okay. In some areas, just by way of example, NSF sponsors an industry university consortium. The one that I am involved in deals with hazardous substances. So there is a group of industries—especially large, chemical firms, in our region that

have identified important issues in which universities can be helpful.

This is housed, in this case, at New Jersey Institute of Technology, which is in Newark, New Jersey, and joins together all of the university people in the area.

In terms of projects, I am interested in the area of risk communication, a project developed in this context dealing with an aspect of Superfund Title III. This is the "Community Right to Know" issue.

In this case, something was broken. Something wasn't working. Host communities for hazardous plants were—it was very important for them to know what was happening in those firms that would affect the emergency planning in case there was a problem.

But the firms were complaining that after all of the time that they used to put out these reports they were not being used. Why were they not being used?

Well, you might have a huge firm like DuPont Chemical dealing with thousands of potentially hazardous chemicals, and the host community would be a small town, and the volunteer emergency planning committee couldn't possibly absorb all of that material.

Our role in the project was to try to develop a better software system that would save the work, or save some of the work for DuPont or the other companies, and yet provide a system of better communications to the host community of what they needed to know.

That kind of project involved undergraduates; it involved graduate students; and it involved a healthy relationship with industry, a back and forth relationship with industry.

It involved people in engineering, and chemical engineering, geographers, and other social sciences.

So in those specific occasions where the topic is suitable and where the marriage is a good marriage, I think it can work very well.

Ms. JACKSON LEE. And it is worth NSF funding it?

Dr. WOLPERT. That is right.

And in the case of these industry-university consortiums, NSF's funding is matched by an equal amount of state funding, and then about three times as much funding from industry.

Having NSF continuously involved in that process, as well as the state, because the states really need to learn in this new federalist system, they need to learn more about the management of research, that is a very good partnership. It is a good idea and it works well.

Mr. SCHIFF. The lady's time has expired.

Ms. JACKSON LEE. Thank you, Mr. Chairman.

Mr. SCHIFF. Mr. Wamp, the Vice Chairman of the Committee, has indicated he will pass on his questioning time.

Mr. Doyle?

Mr. DOYLE. I have no questions, Mr. Chairman.

Mr. SCHIFF. All right, let me ask before we dismiss this panel, does any Member of the panel have one more brief question that they just did not get a chance to answer that they would really like to?

Ms. Jackson Lee?

Ms. JACKSON LEE. I thank you, Mr. Chairman. I did, and it was related to the K through 12 education. What I have gleaned—and I may need to look at this budget a little bit more carefully, or at least what is proposed, and I may not have read it correctly—but just take my inquiry and I will get an update on the information.

But it appears to me that we are losing dollars in those earlier years as it relates to the National Science Foundation. That raises a great deal of concern with me as it impacts a question asked recently by the gentlelady.

I would ask any one of the panel to answer the question for me as to what impact do we have as we diminish opportunities for our youngsters in the K through 12, primarily even educate—excuse me, middle school and elementary school, to have access to the sciences or to the exposure to what would ultimately result in maybe some interest for future research prospectively.

Anyone might answer that.

Mr. SCHIFF. I would intervene, for a second, just to ask—on what is an important subject—for as brief as possible a response. We are on the second round, and we need to get to the second panel.

Ms. JACKSON LEE. I thank you, Mr. Chairman.

Mr. SCHIFF. I yield to the panel now.

Dr. HERMAN. I think this is definitely a critical question for the Foundation and for yourselves. The issue, as I understand it, is one where there has been significant investment made in this area.

What is being called for now, if you will, is sort of a leveling out at this point to assess the results of the investment. I guess this is one area, if you will, of accountability where I think we always have to be concerned.

The only thing I could refer to is my own testimony where I was concerned about how universities, if you will, affect us directly, and that is through the undergraduate education and the education of the next generation of teachers in particular.

So I have great sympathy with your point, Congresswoman Lee, but I do think that Director Lane more or less has it correct, if you will, in the sense of let's take stock now and see where we are going and see the effectiveness of the programs.

But I am very concerned about the point you raise about cutting the access down.

Mr. SCHIFF. Dr. Wolpert and Mr. Sawyer, if you desire to add an answer to that briefly, please go ahead.

Mr. SAWYER. That is my understanding, as well.

When I asked that question of the NSF, they assured me that there was no diminution of the desire or the effort, but the situation is they wanted to be sure they evaluated which of the initiatives were more effective before they invested further in them to make the effective investment. I think that is logical in any creative scientific endeavor is to stop, as you take a big step, and make sure you are going in the right direction. So it makes a lot of sense.

Mr. SCHIFF. Ms. Morella, I believe you desired to be recognized?

Mrs. MORELLA. But I am going to make it very brief.

It was simply in response to three series of articles that were in The Washington Post sometime ago. One of them had to do with

Basic Science. It seemed to imply that we have a plethora of scientists and that we really cannot utilize them all.

I just wondered if anyone wanted to just briefly comment on is that accurate or not, and do we need more?

Mr. SCHIFF. Let me emphasize that word "briefly" that you just heard from Mrs. Morella.

Dr. HERMAN. I think there is a certain, if you will, unemployment situation at this point. But part of that is, if you will, maybe perhaps the end of a retirement age at the universities. So the universities are not in a position to absorb the production, if you will. The pendulum is not quite in the right place.

But I think what is happening now is a much broader education of scientists and engineers which were placed in a number of different venues—even mathematicians on Wall Street. I think this opening up of education really is sort of a broadening of the educational activities and is one way to address the problem.

Mr. SCHIFF. Once again, Dr. Wolpert?

Dr. WOLPERT. I just wanted to say, very briefly, that especially at the undergraduate level, the improved resources and teaching in the sciences is helping to make better citizens in a very complicated world.

Even if that is not their selected career, these are good investments.

Mr. SCHIFF. All right. Thank you very much.

Let me thank the first panel for your very expert—

Mr. BARTON. May I ask just one question?

[Laughter.]

Mr. SCHIFF. Mr. Barton, you are so fast I did not—Yes, sir. I apologize for not recognizing you.

Mr. BARTON. No. I was here earlier, and we had the vote and I got caught up. I have just one question that I would like—

Mr. SCHIFF. Mr. Barton, you are recognized for five minutes.

Mr. BARTON. Well it will not take that long.

Mr. Sawyer, in your testimony you recommended that the name of the National Science Foundation be changed to the National Science and Engineering Foundation.

Would you like to elaborate on that?

Mr. SAWYER. Always.

[Laughter.]

Mr. SAWYER. I think it is imperative that we identify the business of the National Science Foundation. We were given equal stature within the NSF in 1985. But I think for the guidance of the young people that are entering the professions of science and engineering, it is important to know that there is basic research function in engineering; that engineering is a career opportunity; and that when you search for the results of basic research, you can look at the National Science Foundation to obtain information on basic research in engineering.

I think it is proper to have any organization named for the business that the organization is in. So it is not to diminish science in any way. I think basic science knowledge is as important to the webbing of my grandchildren as basic engineering knowledge.

So I think it makes sense for guidance of those of us in the public to know that it is an engineering foundation. So I see no reason

why it should not be called the National Science and Engineering Foundation.

Mr. BARTON. I thank you, sir, and I thank the Chairman.

Mr. SCHIFF. I thank you, Mr. Barton.

Now I would like to thank the first panel for your expert testimony and your contribution to this subject.

I would like to welcome the second panel to come up and take their appropriate seats. While the second panel is coming up, I want to say that I suspect that most people in this room have been involved in one way or another in Congressional hearings in the past, but for those of you for whom this may be the first you have seen, the comings and goings of Members may seem a little bit disconcerting.

I want to tell you that it is necessary just because in the House of Representatives so many different things are always going on at the same time, other Committees, Floor action, constituents, and so forth.

I want to make the point that the lady with the mask is repeating all of the words that are said here, and all of these words are made a permanent part of the record which is then disseminated to all of our colleagues. So I want to assure you that all of the testimony is made a permanent part of the record and is available to all Members of the House of Representatives.

With that, I would like to introduce the panel. I am told that Mr. Bloch's plane was late and he is not here yet, so let me introduce the panel members who are here now:

First is Dr. Cornelius J. Pings, President of the Association of American Universities. He is also representing the National Association of State Universities and Land Grant Colleges.

Dr. Rita Colwell is President of the University of Maryland's Biotechnical Institution and the American Association for the Advancement of Science—and, as I was reminded, is no longer president-elect but is now the president of that organization.

And, Dr. Pamela Ferguson is President of Grinnell College in Grinnell, Iowa, representing the Associated Colleges of the Midwest, the Great Lakes Colleges Association, and the Central Pennsylvania Consortium. Is that right? Central Pennsylvania Consortium?

Dr. FERGUSON. Yes.

Mr. SCHIFF. Grinnell is in Iowa, though, right?

Dr. FERGUSON. Yes, sir.

Mr. SCHIFF. I just wanted to make sure I had that right.

All right, with that, let me say again to the panel that, without objection, your written statements and the written statements of the panel before you will be made a permanent part of this record. I therefore invite you to proceed as you think appropriate.

You may summarize, if you wish, so we can go straight to questions. I would like to begin with Dr. Pings.

**STATEMENT OF DR. CORNELIUS J. PINGS, PRESIDENT ASSOCIATION OF AMERICAN UNIVERSITIES, WASHINGTON, D.C., ALSO REPRESENTING THE NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES**

Dr. PINGS. Thank you, Mr. Chairman.

It is a pleasure to join you this morning. I am president of the Association of American Universities, a position I have been in for two years. Before that, I was Provost for 12 years at the University of Southern California; prior to that, 22 years as a Professor of Chemical Engineering and Chemical Physics at Cal Tech where I was a card-carrying bench scientist.

I am here today on behalf of universities and colleges in every state which perform the research and education projects that are funded by the National Science Foundation, the members of the AAU and the Association of State Universities and Land-Grant Colleges.

As you have had affirmed by your prior panel, the National Science Foundation is crucial in the affairs of our nation. The Foundation is a predominant source of funds for many important fields of science and engineering research. Regardless of the strategic or fundamental labels, over which we sometimes struggle, one might assign to any areas of work at a given time, the Foundation supports research and education for the long term in subjects of vital national importance.

A majority of the funded projects support the work of individual investigators and their small teams of students and technicians. NSF funding of course has also leveraged other private and public sector funds to provide the additional resources to undertake these activities, and the agency programs have stimulated new collaborations among educational institutions and industrial partners which does indeed speed the flow of new knowledge into the technology base. I will turn to the questions you framed and comment on each. The first was about the balance between investigator-initiated research and strategic.

I believe that in recent years that debate unfortunately has become enmeshed in a semantic tangle which occasionally makes it difficult to sort out the issues. The more so because, as said by the prior panel, it really is often impossible to make clear distinctions.

A significant portion of the individual NSF projects are indeed investigator initiated. Fundamental research performed by individual researchers in small groups which collectively nevertheless are fulfilling strategic objectives. Sometimes the work is performed under the rubric of strategic objectives as identified by the Foundation.

I think NSF practices appear to remain true to the norms of its academic science constituency. NSF's annual figures on the proportion of NSF work that is investigator initiated has remained relatively stable. About two-thirds is in response to investigator-initiated proposals.

It is also important that this question that you posed not be limited solely to the National Science Foundation. Several mission-oriented agencies play a role in this area, and their plans need to be considered, as well.

Should there be movement in these agencies toward more applied areas? And there is some suggestion to that. That proposes a particular need for NSF to protect and possibly enhance support for basic knowledge in the underlying applied areas.

The second question is about the balance between research and education activities.

At the undergraduate level, NSF has an opportunity to play a more direct role in science education, I believe, by improving the modernization of science programs for both science and non-science majors.

At the graduate level, as you well know, university graduate education and research are intertwined, and each activity is enriched by that relationship.

The Foundation has long recognized that in a relationship and fosters it in the support of both graduate education and research.

Most research grants carry support for the graduate students. We urge the Foundation to maintain this close and productive interconnection between graduate education and research.

I must acknowledge my disappointment that the NSF submission this year did not request funding for a new class of students in NSF's new Traineeship Program. I think that is indeed a setback.

The third major category you asked about was the growth for academic research facilities and whether that should be provided at the expense of the research program support.

I don't think there is disagreement on support of the state of art university research facilities. To pick up on a comment of the prior panel, I don't think the fundamental problem here is fixing the leaky roofs. Indeed, there is an argument and a preciser one that might be made that that is an ongoing depreciation and maintenance problem that should be attended to.

That still stops far short of addressing the prodigious costs involved in providing new laboratories, particularly as young investigators come into our system. I think there ought to be ways that we could continue to focus on that need.

We continue to believe that there should be a multi-agency initiative to renovate existing research laboratories, and to construct new facilities when warranted—particularly in expanded areas of science and engineering.

We would hope that the NSF portion of that multi-agency research facility initiative would grow in time to perhaps several hundred million dollars annually as the NSF portion.

The fourth question:

Fields of science engineering that have the promise for importance, and should NSF reallocate funds?

Well, this is a pertinent question for planning of future investments. I know it is a matter of concern among NSF leadership on an ongoing basis.

We do not pretend to have a full inventory of feels and measures of adequacy of support, and I can assure you that in most cases there would not be agreement between those in the field and those that look at it from without.

Now having said that, I do note that electrical engineering, aerospace engineering, mechanical engineering, computer science, are supported by a number of agencies including NSF. Chemical engineering, to a lesser extent, civil engineering, look to NSF almost exclusively for support of their academic research.

Additionally, there are certain branches of biology such as environmental and plant biology, some sub-branches of mathematics and the academic research and atmospheric, geological, and ocean-

ographic sciences that depend in large amount for continuance of their NSF support.

The fifth question:

Is NSF moving quickly enough to increase grant size and duration? I don't think this is a critical problem. Although the move seems to be in the right direction, we certainly favor the granting of larger awards for highly successful research teams.

Indeed, efforts should be made to cut down the amount of time scientists spend writing and reviewing proposals whenever possible. I think that could indeed increase the productivity of our leading science faculty members.

Mr. Chairman, thank you and the Committee for this opportunity to talk with you this morning. I have provided extended testimony in writing.

[The prepared statement of Dr. Pings follows.]



**National Science Foundation Reauthorization**

U. S. House of Representatives  
Committee on Science  
Subcommittee on Basic Research

Testimony by:  
Cornelius J. Pings  
President  
Association of American Universities

on Behalf of:  
Association of American Universities  
National Association of State Universities and Land-Grant Colleges

March 2, 1995

Mr. Chairman and Members of the Subcommittee, I am Neal Pings, President of the Association of American Universities. Prior to coming to Washington, I was the Provost at the University of Southern California, and prior to that, Vice Provost and Dean of Graduate Studies at the California Institute of Technology. While at Caltech, I also served as Professor of Chemical Engineering and Chemical Physics. Additionally, I have served as chairman of the National Academy of Sciences Committee on Science, Engineering and Public Policy, in which we wrestled with many issues similar to those you face in this subcommittee. I appreciate the opportunity to share in your deliberations concerning the reauthorization of the National Science Foundation.

I am here today on behalf of the universities and colleges in every state which perform the research and education projects funded by the National Science Foundation—the member universities of the Association of American Universities (AAU) and the National Association of State Universities and Land-Grant Colleges (NASULGC).

The breadth of demands and expectations for the National Science Foundation has never been greater. Our country's need for research and science education continues to grow as private industry cuts back on fundamental research, and the need for a technologically skilled work force is dramatically evident in economic news.

As you know, former President Reagan urged that the budget of the Foundation be doubled in order to better match national needs with agency activities. Even though growth in R&D subsequently fell far short of doubling, Congress, and in particular this Committee, maintained strong bipartisan support for the agency and its mission.

#### The Role of NSF

People are our most precious natural resource. A work force with sufficient skills and learning holds the key to our progress and our economic future. The fundamental purpose of universities is learning through both research, which creates new knowledge, and teaching, which transmits this knowledge to students and to the people and businesses of our nation.

Learning occurs at universities at all levels—for precollege students and their teachers through a large array of courses, math and science camps, and seminars; at the undergraduate level in both course work and increasingly as assistants on research projects; at the graduate and professional levels through seminars and research projects for deeper and more specialized knowledge; for part-time students seeking to further themselves at all stages of their careers through continuing education; and at the faculty level as part of the process of scientific research and discovery.

The National Science Foundation is crucial to these university activities. NSF is the predominant source of funds for many important fields of science and engineering research. Regardless of strategic or fundamental labels one might assign to any areas of work at a given time, the Foundation supports research and education for the long term in subjects of vital national importance.

A majority of the funded projects support the work of individual investigators and their small teams of students and technicians. NSF funding also has leveraged other private and public sector funds to provide additional resources to undertake these activities. Finally, agency programs have stimulated new collaborations among educational institutions and industrial partners which will speed the flow of new knowledge.

### **Balancing Research Opportunities and Societal Demands With Resource Constraints**

Expert and balanced judgment is key in determining priorities for the allocation of resources supporting the scientific enterprise. Promising research opportunities and societal needs for answers to specific scientific and technical problems will almost always outstrip available resources. There are no absolute formulas or rules to follow in dividing the funds available, and a substantial increase in support is not always a viable solution, particularly given present-day fiscal constraints.

This Committee is responsible for providing guidance and oversight to the National Science Foundation as it attempts to meet the challenge of allocating its resources in the most effective manner. We believe the questions you posed prior to this hearing provide a useful framework for discussing important aspects of the Foundation's future. Our perspectives on these questions follow:

#### **1. Is the balance between curiosity-driven and strategic research at NSF correct, and what criteria should be used to determine the proper allocation?**

In recent years, debate has unfortunately become enmeshed in a semantic tangle which makes it difficult to sort out the issues. Moreover, it is often impossible to make clear distinctions. A significant portion of individual NSF projects are investigator-initiated, fundamental research, performed by individual researchers and small groups, which collectively are fulfilling a strategic objective, or performed under the rubric of strategic research.

Indeed, NSF practices appear to remain true to the norms of its academic science constituency. NSF annual figures on the proportion of NSF work that is investigator initiated have remained relatively stable—about two-thirds of NSF funded research is in response to investigator-initiated proposals. For FY 1996, the Foundation approximates that some \$1.57 billion of the \$2.45 billion proposed for the Research and Related Activities portion of the budget will be investigator-initiated research. This will include research categorized as both fundamental and strategic.

It is also important that this question not be limited solely to NSF. Several mission-oriented agencies play a role in this area, and their plans need to be considered as well. The Departments of Defense, Agriculture and Energy; the National Institutes of Health; the National Aeronautics and Space Administration (NASA); the National Institute of Standards and Technology (NIST); and the Environmental Protection Agency (EPA) continue with programs of applied and directed research augmented in different ratios by basic research. Movement in these agencies toward applied areas suggests a particular need for NSF to protect, and if possible enhance, support for the basic knowledge in the underlying disciplines.

Our recommendation, then, is to maintain a strong basic core, recognizing that as each field is vibrant and expands, some level of increasing resources will be needed to sustain researchers and instrumentation. Marginal growth should be made in strategic areas in which there is a strong national need and for fields that carry the most promise. However, when additional funds target a specific area of engineering, for example, for the possible benefits of shorter term payoffs, there also ought to be a complementary investment made in the core engineering research, nondirected, to build the base for future harvesting. We must never forget that a significant amount of breakthrough research results comes from serendipity in research.

## 2. Is the balance between research and education activities correct?

Both are of great importance and yield national benefits. The federal role in support of education differs significantly across levels of education, assuming a proportionately greater and more direct role at more advanced levels. We believe that this differentiation should be incorporated into the science education mission of the Foundation as well. Thus, at the elementary-secondary level, the Foundation's role in developing human resources for science and engineering should be primarily to test, demonstrate, and serve as a catalyst for the development and operation of effective science education programs. At the undergraduate level, the Foundation has the opportunity to play a more direct role in science education, for example, by encouraging the improvement and modernization of science programs for both science and nonscience majors.

In this country, university graduate education and research are inextricably intertwined, and each activity is enriched by that relationship. The Foundation has long recognized that interrelationship and fosters it in its support of both graduate education and research. The Foundation's research programs support both research and graduate education through research assistantships, and the NSF Fellowship Program and the Graduate Traineeship Program enrich both present and future research by drawing some of the nation's most talented college graduates into graduate education in science and engineering. We urge the Foundation to maintain this close and productive interconnection between graduate education and research.

We would advise against the adoption of a rigid formula in allocating resources between research and education activities. Instead, we might suggest criteria such as the following, for judging the relative payoffs to additional investments.

For education programs:

- How effective are present programs? Are the appropriate models and information being developed to enable the lessons from these programs to be broadly adopted across the country? Are these initiatives of sufficient value that they should be extended to other portions of the population (students, teachers, geographic areas)?
- What is the size of the target population; how much would the expansion of these programs cost?

- How effectively used (readily absorbed) would additional funding be for the targeted recipients?

For research:

- Are there fields of science that exhibit major promise for research advances but are relatively underfunded? Are there areas of national need that would be well served for additional research in particular areas?

- What are the demands on each field? How do they compare in terms of sizes of awards versus the needed level for particular kinds of research? What is the proposal pressure of excellent, but nonfunded awards?

- How are academic research teams and university departments faring in acquiring and maintaining instrumentation vital to performing their work? Are research awards of sufficient magnitude or are there sufficient special awards for instrumentation to enable work to proceed?

**3. Should the growth for the academic research facilities program be provided at the expense of research program support? What level of funding should be provided to the academic research facilities modernization program?**

I do not believe there is any disagreement on the importance of state-of-the-art university research facilities to conduct today's advanced science and engineering research. Similarly, there is strong consensus that, despite substantial university investment in recent years, there remains a significant deficit in the state of academic research facilities. These needs are significantly greater than the capacity of the NSF program, and although NSF Director Lane has noted the substantial importance of this issue, I understand he does not believe NSF can address it further under present fiscal constraints.

We continue to believe there should be a multiagency initiative to renovate existing research laboratories and construct new facilities when warranted, particularly in expanding areas of science and engineering research, and hope that the NSF portion of a multiagency research facility initiative would grow, in time, to several hundred million dollars annually.

In recent years, there has been significant growth of NSF resources for research in areas of science and engineering that exhibit exceptional promise of advance and respond to societal needs. Some of these areas, such as materials, manufacturing, and high performance computing and communications, require facilities substantially different from other areas of present research. Since there have not been federal funds for infrastructure to accompany the increase in federal funds for research, universities have had to raise private, state-government, or borrowed funds in order to undertake this additional research in these areas of national need.

4. **What fields of science and engineering that have significant technological promise or importance for public policy formulation are not adequately funded by NSF? Should NSF reallocate funds from fields for which it provides only marginal support relative to other funding sources to higher priority areas that are now underfunded?**

While this is certainly a pertinent question for planning of future investments, we do not pretend to have a full inventory of fields and measures of adequacy of support. Nor in most cases would there be agreement between those in the field and those that look at it from without.

Having said that, electrical engineering, aerospace engineering, mechanical engineering, and computer science are supported by a number of agencies including NSF. But chemical engineering, and to a lesser extent civil engineering, look to NSF almost exclusively for support of academic research. Additionally, certain important branches of biology, such as environmental and plant biology, mathematics, and academic research in atmospheric, geological, and oceanographic sciences, depend in large part on NSF for their continuance.

5. **Is NSF moving quickly enough to increase grant size and duration? Should NSF place more importance on investigators' track record in making research awards and give seasoned investigators longer awards?**

Given current fiscal pressures, NSF efforts in this area are commendable. While the funding rate has remained constant at 32 percent over the last several years, the average annualized award size is rising from \$71,144 in FY 1994 to \$77,700 in FY 1996, and the median annualized award size is rising from \$55,977 to \$61,100. The average duration is also slowly rising from 2.6 years in FY 1994 to 2.8 years in FY 1996.

We favor the granting of longer awards for highly successful research teams. Efforts should be made to cut down the amount of time scientists spend writing and reviewing proposals whenever possible, as it could increase the productivity of leading researchers.

#### **The NSF and the Nation's Future**

The nation's investment in NSF is a very important one. It is difficult to imagine where the nation would be without the basic research and the human capital that the Foundation's programs have developed. Our success in basic research has provided the basis for new industries, such as biotechnology and microelectronics, and the fundamental understanding of natural phenomena that assisted in the monitoring, remediation and design of products to avoid environmental degradation. We need to remind ourselves that it was the human capital, trained and tested in basic research, that has applied basic knowledge to the national priorities in government and industry.

Mr. SCHIFF. I thank you, Dr. Pings.

Doctor—oh, before recognizing you, I believe that Congresswoman Morella desires to be recognized.

Mrs. MORELLA. Thank you.

Just briefly, Mr. Chairman, I wanted to recognize the fact that Dr. Colwell is a constituent, but also not only are we all proud of the fact that she is the president of the American Association for the Advancement of Science and the University of Maryland Biotechnical Institute, but the fact that I just heard that the University of Maryland Biotechnology Institute has received an award of \$1 million from the Lucille Markey Charitable Trust for their work on marine natural products to be carried out both at the Columbus Center in Baltimore and the Center of Advanced Research in Biotechnology in Montgomery County, Maryland.

I am just very proud of her, and I thank you for the opportunity to acknowledge that before she speaks.

Congratulations, incidentally, on that award.

Mr. SCHIFF. Thank you, Congresswoman Morella.

Dr. Colwell?

**STATEMENT OF RITA COLWELL, PRESIDENT UNIVERSITY OF MARYLAND BIOTECHNICAL INSTITUTE AND AMERICAN ASSOCIATION FOR ADVANCEMENT OF SCIENCE, WASHINGTON, D.C.**

Dr. COLWELL. Thank you very much, Congresswoman Morella.

Good morning, Mr. Chairman.

I think I can just barely say good morning, since it is just before noon, and Members of the Subcommittee, I thank you very much for inviting me to testify today on the reauthorization of the National Science Foundation.

As you know, the AAAS is the largest organization of natural and social scientists and engineers in the United States and will soon celebrate their 150th birthday. We also publish Science Magazine.

I would also like to note that I am past president of the American Society for Microbiology, the world's largest single member life sciences society.

I mention that only because I am going to be using a couple of examples in my testimony from the life sciences.

I would also add that I was a member of the National Science Board, appointed by President Reagan.

I would like to begin my testimony by providing some overall comments on the President's proposed fiscal year 1996 budget for the National Science Foundation.

I am going to focus my remarks on the NSF budget within a broader context, especially as it relates to trends in funding research and development within the overall Federal budget.

I will speak very briefly to several of the questions posed earlier to Dr. Lane by the Subcommittee and included in your letter of invitation.

I will just hit a few highlights in my own testimony. The details of course can be found in my written statement.

In light of the constraints imposed by the ever-tightening caps on Federal expenditures that are in place and the renewed calls to re-

duce the size of the Federal Government and cut spending, it is therefore gratifying to see that the President requested a 2.6 percent increase in his budget for NSF for fiscal year 1990-96.

Although this is not an increase in real inflation-adjusted terms, most of us regard it as respectable in the current budgetary environment.

We should be aware, however, that the apparent overall increase is largely due to the fact that NSF is relinquishing \$132 million in fiscal 1995 facilities funds, thus reducing the base against which the fiscal year 1996 budget is compared.

If you compare the fiscal year 1995 and the fiscal year 1996 funding levels before adjusting for the proposed rescission, the NSF budget is essentially flat and actually declines about 3 percent in real terms.

Nevertheless, we are pleased that the budget is one that maintains the state of affairs for the NSF.

Considering the proposed NSF budget in the context of other federal R&D agencies, we have a little concern. Although relative to other federal programs, the R&D programs would seem to be in really good shape, they are far from exempt from the overall austerity that is being imposed on the federal budget.

In fact, according to preliminary figures provided by the AAAS staff to me, the total R&D funding in the budget actually shows a net decline of two-tenths of a percent in current dollars, and 3.1 percent in constant dollars, compared to the fiscal year 1995 budget. We have provided a table, which I have included in my testimony.

So this appears to be the first time in recent memory that a President's proposed budget has not contained at least a current-dollar increase for total R&D.

So while we in the research community recognize the importance of reducing the deficit, we are really concerned about the proposal that has the potential of sacrificing the long-term investment in our future in favor of short-term considerations. Let me turn to a few questions raised in your letter: The balance between curiosity-driven and strategic research.

This has been a subject of an intense discussion in the community and of course here today.

John Armstrong, a former president of the IBM Corporation, has contributed a number of insights in his paper, "The Concept of Strategic Research." He presented this at a Forum last year at the National Academy of Sciences.

I would be happy to submit the paper for the record, if you wish. Armstrong spoke about the relation between basic and applied research and the meaning of "strategic."

He observed that basic research is best defined not in terms of process but in terms of results. It leads to an understanding.

Let me give an example. A very, shall I say, simple, plain, down to earth example.

In the 1960s a scientist named Tom Brock, who was then at Indiana University, and he is now at the University of Wisconsin as a retired professor, was very curious about bacteria that lived in extreme environments.



He set up a laboratory, a mobile laboratory, in a trailer and he parked it by the Old Faithful, one of the geysers at Yellowstone Park.

This was in the 1960s. He isolated bacteria that were able to grow at very high temperatures, nearly boiling water temperatures.

What he provided were some cultures that ended up in a culture collection at the American Type Culture Collection in Maryland.

Two years ago, a scientist from California had the idea that you could replicate DNA, very small amounts, if you had an enzyme that operated at very high temperatures.

There is the basis of the polymerase chain reaction for which this California Scientist, Gary Mullis, won the Nobel Prize.

This was curiosity-driven research, if you wish, but it ended up in the PCR reaction, polymerase chain reaction, which is now used in criminal case testing, establishing paternity, detecting trace amounts of DNA from fossils, and determining from skeletal remains centuries ago that individuals died of a given disease because what remains is the DNA of the bacteria that could be detected. This is now a major industry.

I think it is very important to point out that there is a clear, ultimate practicality to even the most curious of research that is done.

Let me give another example, because Armstrong also defined applied research as research aimed at making something work.

Strategic research is research that can reasonably be expected to contribute to these goals, including understanding the understanding-driven basic research.

Let me give a second example of the oysters in the Chesapeake Bay.

At the turn of the Century, millions and millions, hundreds of millions, of bushels of oysters were harvested from the Chesapeake Bay, but in recent years there are dozens of bushels, maybe a hundred bushels, a few thousand bushels, but nowhere near the productivity of the past.

We were asked at the university to carry out research to solve this problem.

We would call this strategic research. But in doing the research, we found that understanding how oysters set was very important.

We determined that it was in fact bacteria that formed a film on the surface that released a compound, L-dopamine, released by a bacterium—you recognize the compound because it is used to treat Parkinson's disease—but that is a signalling compound that entrained the oyster to settle.

Furthermore, that film on which the oyster settled turned out to be a kind of a super glue. It led to a patent being filed and a license being taken out by a young company that was then formed specifically to exploit that discovery.

That company has expanded and is now known as Oceanix Company north of Baltimore, near Baltimore, and has now expanded to a mid-level pharmaceutical firm.

Now the point I would like to make is that the issue is not of strategic versus curiosity-driven or understanding-driven research.

There is no inherent conflict between strategic research and research done by individuals driven by a desire to understand nature.

The strategic goal for which the research is supported by a sponsor or by a Federal agency or by industry and the motivations of the individual researchers are different things, but they end up with the end result being of benefit to the country.

Our science policy should seek to maintain an overall healthy and vigorous scientific enterprise, including both basic, the understanding-driven research, and applied research, the research to make something work, while giving special emphasis and attention to maintaining the world leadership in those areas that are likely to contribute most directly to our national goals.

Just a word about the balance between research and education.

I do think that we must not lose sight of the fact that science education is crucially important to the future of the research community, but that it is probably a good time to consolidate the gains we have made in science education and to invest available budgetary growth in research, maintaining the science education.

A comment regarding academic facilities funding.

The NSF academic facilities account is facing a substantial cut in fiscal year 1996, as well as a rescission of appropriated fiscal year 1995 funds.

There has been some discussion of the need to maintain the facilities, but let me point out that the government creates unfunded expectations by supporting and relying on R&D without adequately funding the necessary facilities.

I would point out that the facilities house the scientist who contributes to economic development in our counties, our states, our cities across America.

Furthermore, the funding provided by the NSF leverages state and private funding, as pointed out by Dr. Schmitt in the previous panel, and I would point out that in Montgomery County the Central for Advanced Research is a partnership between a Federal laboratory, industry, and the University and private funding.

This is the way I think leverages can be done very effectively.

Nevertheless, NSF is only a little over 3 percent of total Federal R&D in approximately 7.5 percent of Federal non-defense R&D.

We need a comprehensive, broadly based Federal effort, including but not limited to NSF facilities.

Let me turn to grant size and duration. In my experience, a researcher's track record is already critically important in the grant review process.

I don't think that more emphasis on this is required, but it is worth keeping in mind the problems that young investigators face when applying for grants.

I can speak from personal experience, being, in mid-life a seasoned, career senior scientist, with two daughters, one of whom has just finished an M.D. and is working on her Ph.D., having gone to Colgate University and is now at the University of Illinois.

The other has a Cornell Bachelor of Science Degree and has just finished her Ph.D. at Washington University in St. Louis. Both are launching their careers.

I know very well that they are facing, along with their confreres, a very competitive, very difficult research funding competition, but also a very difficult job market.

Nevertheless, I would point out that there are two things that can be offered.

One is the notion of awarding the seasoned investigator longer grant periods has appeal.

This would cut down on paperwork for both the researchers and the NSF.

However, we must maintain an environment that will enhance our young researchers.

We must—as we have just learned, there is a decline in the number of young investigators even bothering to apply for NIH funding, and certainly for NSF funding—

So we must maintain a basis for these young investigators.

In conclusion, I would say that we at the AAAS are reasonably satisfied with the proposed NSF's budget for fiscal year 1996, given the current fiscal situation.

However, the overall picture and longer term outlook for R&D, including academic research, does not appear to be good, and I have provided some graphical data in my presentation.

To remain world leaders in science and technology, we have to maintain and expand our scientific capabilities across the board.

Without a continued inflow of funds, these capabilities will be diminished.

We have to remember. We are in a tough competition with the rest of the world.

I would like to close by speaking out on the need for public policy research. My colleagues in the social sciences have a great deal to contribute to this area.

For example, if we had paid more attention to the social aspects of nuclear power, for example, we would probably not find ourselves in quite the dilemma that we are in.

I would point out that in the case of biotechnology, it is very important to examine the ramifications, the social ramifications of our findings, not to prevent it, not to impede it, but to be able to understand that. For example, in being able to determine that a child is born with a disease that can be detected only by the DNA testing, it is very important to be able to investigate and to inquire about the opportunities for insurance, the opportunities for education, all the social and ethical implications that go with it.

Mr. Chairman, this committee has a long record of understanding the importance of research, supporting it, and providing the oversight and constructive criticism it needs to thrive.

We are grateful for the invitation to testify before this Subcommittee on Basic Research, and we are pleased to see that the Republican leadership is continuing to uphold those traditions.

Thank you.

[The prepared statement of Dr. Colwell follows.]

**Statement of  
Dr. Rita Colwell  
President  
American Association for the Advancement of Science  
Washington, D.C.**

**before the**

**Subcommittee on Basic Research  
Committee on Science  
U.S. House of Representatives**

**Hearing on the National Science Foundation Reauthorization**

**March 2, 1995**

Good morning, Mr. Chairman and Members of the Subcommittee, and thank you for inviting me to testify before you today on the reauthorization of the National Science Foundation. I am Dr. Rita Colwell, President of the University of Maryland Biotechnology Institute in College Park, Maryland. I am testifying today in my capacity as President of the American Association for the Advancement of Science (AAAS).

Founded in 1848, AAAS currently has 143,000 individual members and 300 affiliated societies. We are the largest organization of natural and social scientists and engineers in the United States and the world's largest federation of scientific and engineering societies. We publish *Science* magazine and maintain a wide range of programs aimed at improving public policy, education, and public understanding of science and technology.

Among AAAS's most prominent public policy activities is its annual series of analyses of federal funding for research and development. Since 1976, with the aid of its affiliated associations, AAAS has been monitoring R&D in the federal budget. The Association publishes a report on the President's proposed budget each spring, holds a colloquium on science and technology policy in April, and prepares a report reviewing congressional action on R&D in the federal budget each fall. In addition, several months ago, in response to a recommendation from the Carnegie Commission on Science, Technology, and Government, AAAS established a new Center for Science, Technology, and Congress to provide timely, objective information on

current issues in science and technology to Members of Congress and staff. The bulletin *Science & Technology in Congress* is distributed free of charge to Members' offices monthly when Congress is in session. I believe these and other activities provide AAAS with a well-informed view of trends in federal funding for science and technology and the contributions that research and education can make to the nation's economy, security, and quality of life.

I would like to begin my testimony by providing some overall comments on the President's proposed FY 1996 budget for the National Science Foundation (NSF). I am going to focus my remarks on the NSF budget within its broader context, especially as it relates to trends in funding for R&D within the overall federal budget. I will also speak to several of the questions posed earlier to Dr. Lane by the Subcommittee and included with your letter of invitation.

#### **NSF FY 1996 BUDGET REQUEST**

Federal funding for scientific and engineering research, as has frequently been stated in this hearing room and in many other venues, is an investment in the Nation's future. In contrast to many other government activities that, worthy as they may be, represent only consumption for today's needs, research programs provide for tomorrow. They are the source of the knowledge and human resources that the Nation needs to provide for its continued security, health, and prosperity. The National Science Foundation is an essential part of our nation's support structure for cutting-edge science and technology. The Foundation provides almost 15 percent of all federal funding for non-defense basic research and nearly 50 percent of all federal support for non-medical basic research at academic institutions. NSF's support for academic basic

research is critical in a wide range of science and engineering disciplines. Without the continued strong support of NSF, our Nation's ability to be a leader in many areas of scientific and engineering research would be severely compromised.

As we in the research community well know, the past few years have been particularly difficult budget-wise. In light of the constraints imposed by the ever-tightening caps on federal expenditures already in place and the renewed calls to reduce the size of the federal government and cut spending, particularly with respect to domestic discretionary programs, it is gratifying to see that the President requested a 2.6 percent increase in his budget for NSF for FY 1996. Although this is not an increase in real, inflation-adjusted, terms, most observers regard it as respectable in the current budgetary environment. However, we should be aware that the apparent overall increase is largely due to the fact that NSF is relinquishing \$132 million in FY 1995 facilities funds, thus reducing the base against which the FY 1996 budget is compared. If you compare the FY 1995 and FY 1996 funding levels before adjusting for the proposed rescission, NSF's budget is essentially flat, and actually declines around 3 percent in real terms.

Looking inside the NSF budget, I am pleased to note that the Foundation's core research activities, contained in its "Research and Related Activities" account, are proposed to increase 7.6 percent over FY 1995. (The increase is actually 9.3 percent if we factor in an accounting adjustment to the LIGO project.) This request, which represents growth of about 4.5 percent in inflation-adjusted terms, shows a commitment to the support and modest growth of basic research activities in the key fields of mathematical, physical, biological, behavioral and social

sciences, as well as in computers and information science, earth, ocean, and atmospheric sciences, and engineering.

My positive view of this trend is tempered, however, by the issue of the rescission in R&D facilities. As noted above, the Administration has chosen to relinquish \$132 million in FY 1995 funding that Congress provided in a "use-or-lose" manner. If you subtract this proposed rescission from the FY 1995 appropriation, FY 1996 funding for Academic Research Infrastructure appears to decrease by about 15 percent to \$100 million. If you treat the appropriated (pre-rescission) level as the base, however, the FY 1996 level declines by more than 60 percent from FY 1995. AAAS's budgetary practice is to use the appropriated level as the base and to consider facilities and operations ("conduct") as comprising total R&D. Thus, the preliminary AAAS budget table attached actually shows a decline of 0.1 percent in NSF's R&D budget in current dollars and a cut of 3.1 percent in constant dollars.

Considering the proposed budget for NSF in the context of other federal R&D agencies gives one further pause. As you know, FY 1996 is likely to be another tight year for federal R&D funding. Although, relative to other federal programs, R&D programs would seem to be in fairly good shape, they are far from exempt from the overall austerity that is being imposed on the federal budget. In fact, according to preliminary figures provided by the AAAS staff, total R&D funding in the proposed budget actually shows a net decline of 0.2 percent in current dollars and 3.1 percent in constant dollars compared to FY 1995. (See attached table.) This would appear to be the first time in recent memory that a President's proposed budget has not



contained at least a current-dollar increase in total R&D. So, while we in the research community recognize the importance of reducing the deficit, we must be concerned about a proposal that has the potential of sacrificing long-term investment in our future in favor of short-term considerations.

With this as background, let me comment on several of the issues that the Subcommittee posed to NSF Director Neal Lane.

#### **BALANCE BETWEEN CURIOSITY-DRIVEN AND STRATEGIC RESEARCH**

As the Members of the Subcommittee know, the balance between curiosity-driven and strategic research in NSF has been the subject of intense discussion and debate in Congress, the Administration, and the S&T policy community for several years. There has been a good deal written and spoken on the subject and some important insights have emerged. John Armstrong, former vice president of IBM Corporation, has contributed a number of these insights in his paper, "The Concept of Strategic Research," which he presented at the Forum on Science in the National Interest about a year ago and which was published in the *1994 AAAS Science and Technology Policy Yearbook*.

Armstrong spoke about the relation between basic and applied research and the meaning of the term "strategic." He observed that basic research is best defined not in terms of a process but in terms of results. In his words, "Basic research leads to a new understanding of how nature works and of how its many factors are interconnected." Such an understanding does not depend

on any single, unique process. He also disavowed the term "curiosity-driven" as a synonym for "basic," suggesting that it is not a frivolous sort of curiosity that motivates researchers, but a search for improved understanding of phenomena and observations. Applied research he defined as "research aimed at making something work," noting that often, in order to make something work it is necessary first to understand it. Nations support research -- both basic and applied - - because they expect it to contribute to better health, a secure defense, and an improved standard of living and environment. "Strategic research," says Armstrong, is "research that can reasonably be expected to contribute to these goals, including understanding-driven basic research."

Thus the issue is not one of strategic *versus* curiosity-driven (or understanding-driven) research. To quote Armstrong again, ". . . there is no inherent conflict between strategic research and research done by individuals driven by a desire to understand nature. The strategic goal for which research is supported [by its sponsor] and the motivations of individual researchers are different things. . . ." At the national policy level we should strive to be sure that basic research that appears likely to contribute to the achievement of society's goals is well-supported. But we should not be so arrogant as to feel that we can predict in any detail which areas of understanding-driven research will ultimately contribute most to those goals. Our science policy should seek to maintain an overall healthy and vigorous scientific enterprise -- including both basic (understanding-driven) and applied research -- while giving special emphasis and attention to maintaining world leadership in those areas that are likely to contribute most directly to our national goals.

## **BALANCE BETWEEN RESEARCH AND EDUCATION ACTIVITIES**

Basically, I think the balance between research and education activities is acceptable. Education activities have grown rapidly in recent years, and this is probably a good time to consolidate those gains and to invest available budgetary growth in research activities. However, we must not lose sight of the fact that science education is crucially important to the future of the research community. NSF plays a unique role in educating the world about science and technology and increasing broader public understanding of science and technology. In the long-term, without continued support of education to provide a strong science and engineering community, an educated, capable workforce, and a public capable of democratic self-government in an increasingly complex, technological world, R&D will not be able to help us achieve our strategic goals.

## **ACADEMIC FACILITIES FUNDING**

As I mentioned previously, NSF's Academic Facilities account is facing a substantial cut in funding in FY 1996 as well as a rescission of appropriated FY 1995 funds. Last year, AAAS reported in its *Congressional Action on R&D in the FY 1995 Budget* that there was a "tension between NSF's emphasis on the conduct of R&D combined with relative neglect of R&D facilities and congressional emphasis on R&D facilities over the conduct of R&D." In fact, Congress appropriated a total of \$250 million for Academic Research Infrastructure, considerably more than was requested by the Administration. Of this, \$132 million was contingent on NSF including a similar request in its FY 1996 budget. In order to make room

for this request within the limitations imposed on its total budget, NSF would have had to trim its FY 1996 request for research activities; it is understandable that NSF chose to fund research over buildings.

In providing this "use-it-or-lose-it" appropriation, Congress was trying to push NSF towards an assault on the huge national problem of deteriorating research infrastructure. Most observers agree that, in the face of the acknowledged backlog of infrastructure needs, a coordinated federal effort is necessary. The agencies that rely on the talent pool found in academia must provide support for facilities where appropriate. The government creates *unfunded expectations* by supporting and relying on R&D without adequately funding the necessary facilities. Research cannot continue to flourish while infrastructure continues to deteriorate, but the problem will not be solved within the confines of NSF's relatively limited budget. In FY 1995, the funds provided for infrastructure at NSF were out of proportion to NSF's size relative to total federal R&D. NSF is only a little over 3 percent of total federal R&D and approximately 7.5 percent of federal non-defense R&D. The federal government should not, however, reduce R&D facilities funding at other agencies and expect NSF alone to support infrastructure renewal. A comprehensive, broadly-based federal effort, including but not limited to NSF, is needed.

#### GRANT SIZE AND DURATION

In my experience, a researcher's track record is already critically important in the grant review process; I do not think that more emphasis on this factor is called for. It is also worth keeping in mind the problems that young investigators face when applying for grants. Increasing the

emphasis on track record could have detrimental effects on younger researchers' chances of receiving grants and establishing themselves in their fields.

On the other hand, the notion of awarding the more seasoned researchers longer grants has some appeal. Presumably, this would cut down on the paperwork for both the researcher and NSF. However, increasing the size and duration of grants requires tradeoffs. Increased size and duration suggests that there will be fewer grants available, again adversely affecting younger researchers. The figures on grant size and duration discussed in the NSF Budget Summary (pg. 41) show a relatively small increase in the size of grants, not much better than inflation though, and a slight increase in duration.

## CONCLUSION

In general, I would say that we at AAAS are reasonably satisfied with the proposed NSF budget for FY 1996, given the current fiscal situation. However, the overall picture and longer-term outlook for R&D, including academic research, are not very good. While we in the scientific community understand that budget constraints are requiring cutbacks in most areas of the federal budget, we believe that research and development plays an important and integral role in the global competitiveness and economic growth of the United States. In order to remain world leaders in science and technology, we must maintain and expand our scientific capabilities across the board. Without a continued inflow of funds, these capabilities will be diminished.

Although our main focus at this hearing is on the FY 1996 budget, I want to conclude by bringing to your attention some disturbing trends that the AAAS analysis has uncovered in examining the outyear projections for the R&D-intensive agencies contained in the President's budget. The attached chart presents these projections compared to FY 1995 levels for several key agencies, including NSF. These projections are, of course, not actual budget request numbers. They are simply estimates of agency and OMB expectations for future years under current budget and economic assumptions. While these assumptions may—and certainly will—change, the future funding patterns they portend are ominous. As you can see in the chart, every one of the agencies expects its budget to decline over the next five years. Some of these declines are substantial. NSF is among the better-off agencies, but it still would expect to lose some \$500 million relative to its current budget level by FY 2000. Should this decline actually occur, it could prove disastrous for academic science and engineering in the United States. The situation will require careful monitoring and vigilance on the part of this Subcommittee and others inside and outside of government concerned with the health of research and the future of the Nation.

The House Science Committee has a long record of understanding the importance of research, supporting it, and providing the oversight and constructive criticism it needs to thrive. We are grateful for the invitation to testify before the Subcommittee on Basic Research, and we are pleased to see that the new Republican leadership is continuing to uphold this tradition.

## AAAS Preliminary Estimate of R&amp;D in the FY 1996 Budget by Agency (budget authority in millions of dollars)

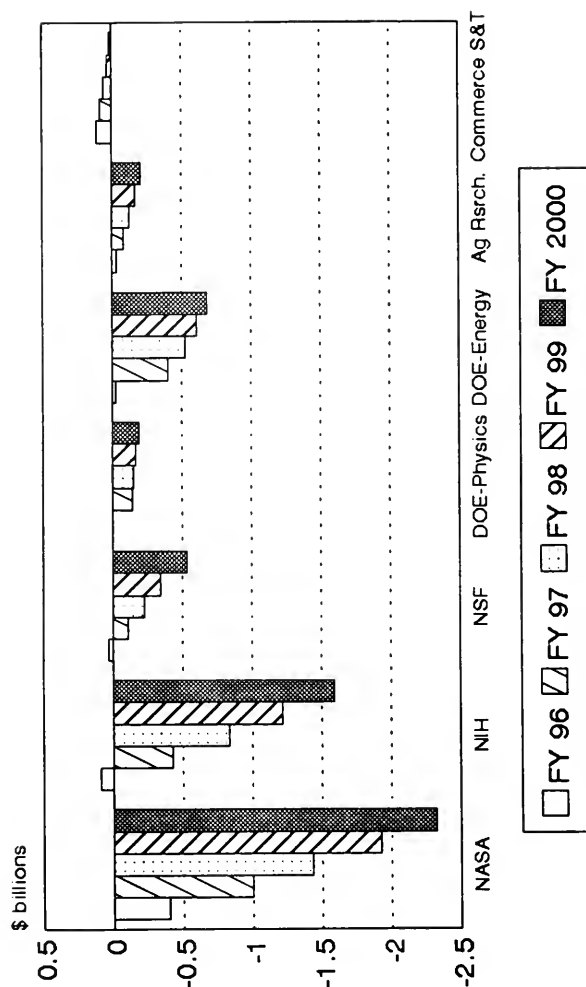
	FY 1994 Actual	FY 1995 Est.	FY 1996 Budget	% Change FY 95-96	
				Current \$	Constant \$
Total R&D (Conduct and Facilities)					
Defense (military)	35,509.6	36,272.2	35,161.2	-3.1%	-5.9%
NASA	9,323.2	9,455.2	9,517.1	0.7%	-2.3%
Energy	6,771.2	6,538.3	7,011.9	7.2%	4.1%
HHS	11,323.5	11,727.0	12,157.1	3.7%	0.6%
NIH	(10,473.5)	(10,840.2)	(11,293.3)	4.2%	1.1%
NSF	2,242.5	2,543.6	2,540.0	-0.1%	-3.1%
Agriculture	1,528.3	1,539.8	1,483.4	-3.7%	-6.5%
Interior	707.6	686.1	679.3	-1.0%	-3.9%
Transportation	640.8	687.0	619.6	-9.8%	-12.5%
EPA	589.9	620.2	681.6	9.9%	6.7%
Commerce	1,061.3	1,286.5	1,404.7	9.2%	6.0%
Education	175.3	174.8	181.8	4.0%	1.0%
AID	315.6	314.0	255.0	-18.8%	-21.2%
Veterans Affairs	276.5	296.9	272.8	-8.1%	-10.8%
Nuclear Reg. Comm.	90.7	82.0	81.8	-0.2%	-3.2%
Smithsonian	133.9	134.8	138.8	3.0%	0.0%
Tennessee Valley Auth.	96.0	88.6	98.8	11.5%	8.3%
Corps of Engineers	51.6	54.6	55.4	1.5%	-1.5%
Labor	62.6	61.8	94.0	52.1%	47.7%
HUD	35.6	40.5	40.8	0.7%	-2.2%
Justice	45.8	53.7	55.1	2.6%	-0.4%
Postal Service	51.0	70.0	72.0	2.9%	-0.1%
TOTAL R&D	71,032.6	72,727.6	72,602.1	-0.2%	-3.1%
Defense	38,299.1	38,837.5	37,929.8	-2.3%	-5.2%
Nondefense	32,733.5	33,890.1	34,672.2	2.3%	-0.7%

Source: AAAS, based on OMB supporting data for R&amp;D exhibits and agency budget documents.

Note: Estimates subject to change based on final confirmation of agency data.

# Outyear Projections for Selected Nondefense Agencies and Programs

Change from FY 1995 level in constant FY 1987 dollars



Zero point = FY 1995 level, in constant dollars

Source: AAS, based on FY 1996 Budget-Analytical Perspectives, Table 6.1.



Mr. SCHIFF. Thank you so much, Dr. Colwell.

Before recognizing Dr. Ferguson, a Member who had to leave for another Subcommittee hearing going on at the same time asked unanimous consent that all Members may be able to submit questions in writing to the two panels.

Is there objection to that request?

[No response.]

Mr. SCHIFF. Without objection, so ordered.

Dr. Ferguson?

**STATEMENT OF DR. PAMELA FERGUSON, PRESIDENT GRINNELL COLLEGE, GRINNELL, IOWA REPRESENTING ASSOCIATED COLLEGES OF THE MIDWEST, GREAT LAKES COLLEGES ASSOCIATION; AND CENTRAL PENNSYLVANIA CONSORTIUM**

Dr. FERGUSON. Thank you for inviting me to address this Subcommittee. My perspective comes from my experience as a mathematician, as well as president of Grinnell College.

Today I speak on behalf of the Associated Colleges of the Midwest, the Central Pennsylvania Consortium, and member institutions of the Independent Colleges office.

I have two points to make related to the question sent, and then we will conclude with two recommendations. My first point is that discussions about the reauthorization of and the budget for the NSF must be based on an understanding of the vital role of a strong undergraduate community plays in serving the national interest.

As you know, the NSF has a very unique mission. Simply put, it promotes both scientific discovery and scientific discoverers. This dual role has in the past sometimes created discussions that pitted research against education.

In your discussions, I would urge you to look at this dual role in a different light. not as opposite sides in the budget tug of war, but as two integrated parts of a whole.

As we look to uphold a position of world leadership in all aspects of science, mathematics, and engineering, the undergraduate sector is the critical link in the national effort to build and sustain a competent and competitive work force.

This is where we prepare the K through 12 teachers, the next generation of science professionals, those who will be corporate and government leaders, and many of the scientifically literate populace.

The undergraduate sector has learned that the best way to prepare both scientists and non-science majors is to get students involved. This happens when research and teaching are integrated, when students starting with the introductory courses work together in hands-on, relevant scientific problem solving.

Our students graduate, whether in science or not, with the ability to ask questions, solve problems, work collaboratively, use technology, and communicate the results of their work.

These are the skills we need in citizens and world leaders of the 21st Century. In the past five years, education from preschool to post-graduate has received roughly 20 percent of the total NSF

budget. We consider this to be a minimum to support a credible education program.

This brings me to second point of my testimony. The NSF and the Nation's colleges and universities must share the responsibility of building and sustaining undergraduate science, mathematics, engineering and technology education. Why should the NSF be involved in building and sustaining undergraduate education?

The answer is obvious. Without these programs, who will be your scientists, your leaders, your teachers.

For example, liberal arts colleges have only 3 percent of the total understand enrollments, and yet we produce 16 percent of the science and math Ph.D.s

In my written testimony, I discuss the academic research infrastructure program which funds the renovation of existing research and research training facilities.

The physical environment for research and research training on campuses across the nation in a crisis situation.

To have programs that teach science by doing science requires spaces that accommodate the active collaborative community. My answer to the question. What level should be provided to the ARI program is, to find it at a level of funding recommended in the authorization of the academic research infrastructure program, \$250 million.

Our past successes and our future challenges finally lead us to make these two recommendations. We ask that this Subcommittee direct the National Science Board to establish a special commission to outline a formal plan of action, including a five-year agenda for all science, mathematics, engineering and technology activities within the Foundation that affects students and faculty, and programs and facilities at the undergraduate level.

The second recommendation is that this Subcommittee takes aggressive action to ensure that the NSF's ability to serve the national interest, particularly maintaining the vital program of science, mathematics, and engineering education, will be preserved.

It is foolish and short-sighted to minimize the importance of education to our Nation's future competitiveness and leadership.

The NSF has the mandate and the power to ensure that our citizenry are scientifically literate, and the developing young scientists have some tools and encouragement to try something new, discover something different; to ask a new question; and to tell us a new answer.

Thank you.

[The prepared statement of Dr. Ferguson follows.]

TESTIMONY  
FOR THE  
SUBCOMMITTEE ON BASIC RESEARCH  
COMMITTEE ON SCIENCE  
U.S. HOUSE OF REPRESENTATIVES  
MARCH 2, 1995

Presented by  
Dr. Pamela A. Ferguson, President of Grinnell College  
Grinnell, Iowa

I am pleased to be invited to address this Subcommittee, and to speak about issues relating to the reauthorization of the National Science Foundation and the NSF FY 1996 Budget Request. I will do this from the perspective of the independent, predominantly undergraduate institution—from Grinnell College and other colleges within the Associated Colleges of the Midwest, and from the Central Pennsylvania Consortium, and other member institutions of the Independent Colleges Office.<sup>1</sup>

I have two points to make:

I. That discussions about reauthorization of and budget for the National Science Foundation must be based on a clear understanding of how a strong undergraduate community serves the national interest. A vital science and mathematics community at the undergraduate level is central to the ability of NSF to achieve the first goal stated in the recently-announced NSF Strategic Plan:

*[The goal to enable] the U.S. to uphold a position of world leadership in all aspects of science, mathematics and engineering [is based on] the conviction that a position of world leadership in science, mathematics and engineering provides the Nation with the broadest range of options in determining the course of our economic future and our national security. (NSF95-24[NEW])*

II. That NSF and the nation's colleges and universities have a shared responsibility to build and sustain undergraduate programs in science, mathematics, engineering, and technology education that serve the national interest; that collectively we must strive to achieve the further goals presented in the NSF Strategic Plan:

*[The goal to] promote the discovery, integration, dissemination, and employment of new knowledge in service to society.... [The goal to] achieve excellence in U.S. science and mathematics, engineering, and technology education at all levels. This goal is worthy in its own right, and also recognizes that the first two goals can be met only by providing educational excellence. It requires attention to needs at every level of schooling and access to science, mathematics, engineering, and technology educational opportunities for every member of society. (NSF95-24[NEW])*

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<sup>1</sup> ICO members include: Allegheny College (PA); Augsburg College (MN); Beloit College (WI); Carleton College (MN); Coe College (IA); Colby College (MA); College of the Holy Cross (MA); College of St. Catherine (MN); The Colorado College (CO); Cornell College (IA); Dickinson College (PA); Franklin and Marshall College (PA); Furman University (SC); Gettysburg College (PA); Grinnell College (IA); Hope College (MI); Kalamazoo College (MI); Knox College (IL); Lake Forest College (IL); Macalester College (MN); Manchester College (IN); Monmouth College (IL); Oberlin College (OH); Ohio Wesleyan University (OH); Pomona College (CA); Reed College (OR); Ripon College (WI); Scripps College (CA); St. Olaf College (MN); University of Redlands (CA); University of Richmond (VA); Wheaton College (MA).

**Testimony: Dr. Pamela A. Ferguson**  
**Subcommittee on Basic Research—House Committee on Science**  
**March 2, 1995**  
**Page 2**

I will conclude by making two recommendations for action by this Subcommittee in the continuing reauthorization process. First, the institutions for which I speak recommend that:

- \* The Subcommittee direct the National Science Board to establish a Special Commission to outline a formal plan of action and a five-year agenda (thereby taking planning into the 21st Century) for all science, mathematics, engineering, and technology (SMET) activities within the Foundation that affect students and faculty, programs and facilities at the undergraduate level.

Further, in the work of this Special Commission, we ask that each sector of the undergraduate community be involved, recognizing the distinctive contribution in SMET education of two- and four-year institutions—ones large and small, public and private—in serving the national interest.

Grinnell College, and those for which I speak, are ready and willing to enter into a new, more productive partnership with the National Science Foundation to pursue national goals. What we need is a mutually-agreed-upon agenda for the coming decade, an agenda that reflects our collective vision. Even if resources do not increase, and perhaps *particularly* if they do not, we must examine present programs and policies to determine if and how they reflect current priorities. That we live in a challenging, changing world is clear to us all. But two of the most critical challenges for us as educators and leaders are to raise the scientific and technological skills of the workforce, and to provide educational opportunities so that all students, no matter what their backgrounds or career aspirations, are prepared to lead lives that are productive and meaningful. We must accomplish this in the most effective, and efficient manner.

My second recommendation:

- \* That this Subcommittee take aggressive action to ensure NSF's ability to serve the national interest, particularly maintaining a vital program of science education at all levels.

This is the 50th Anniversary Year of the founding of NSF, as well as of the end of the Second World War and the dropping of the atomic bomb. NSF was established "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." In the Authorizing Act, the NSF was directed to:

*initiate and support basic scientific research and programs to strengthen scientific research potential and science education programs at all levels in the...sciences [and] engineering...(National Science Foundation Act of 1950)*

Such a mission is no less critical today than at the outset of the Cold War, or in the days after Sputnik. I join my colleagues on this Panel to celebrate the contribution of the National Science Foundation, and to anticipate its continued contribution, specifically my role is to bring your attention to the value of NSF programs that have an impact at the undergraduate level. The current generation of undergraduates—the 12 million students now studying for associate and baccalaureate degrees on over 3,000 campuses across the country—will be responsible for the quality of life and the economic vitality of our nation in the first decades of the 21st Century.

As Director Lane said recently,

*Producing faculty is not the only goal; we need to prepare more young people in science for a wider range of careers. Many professions are going to require a foundation in science and technology to be part of the future of this nation. (Science, November 4, 1994)*

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Increasingly also, as science and technology have an impact on all life, we all need to know more and better science to ensure that students, indeed all of us, are prepared to be productive citizens. Lewis Thomas said it very well:

*We need to know more. We cannot stop where we are, stuck with today's level of understanding, nor can we go back. I do not see that we have a real choice in this, for I can see only the one way ahead. We need science, more and better science, not for its technology, not for leisure, not even for health or longevity, but for the hope of wisdom which our kind of culture must acquire for its survival.*

\* \* \*

In Attachment I is presented some pertinent data about ICO institutions, with comparative data from a select group of universities and colleges. Please note the measurable productivity of this group of institutions; we are in the sector of higher education that has 3% of the undergraduate enrollments and produces about 16% of the Ph.D.'s. We are also leaders in the current effort to transform undergraduate science/math education. Attachment II includes excerpts from the article in the November 7, 1994 *Science* which focused on innovations in classroom and lab, highlighting many of the programs on the campuses for which I speak today.

First, some information about Grinnell, to set the context: Grinnell College is a coeducational, four-year, liberal-arts college which attracts academically talented students from throughout the U.S. and the world. The College stresses academic excellence and social responsibility, with an open curriculum and a strong advising programs. This year our enrollment is 1,295 and our faculty number 133.

Despite our size, the programs in biology, chemistry, and physics on our campus are of national stature. The College is a leading source of science majors in this country, and of those who then earn Ph.D.'s in fields of science. The College graduates over one-third of its students in the sciences, nearly six times the national average. Grinnell ranks thirteenth across the nation in the number of women science majors who go on to earn Ph.D.'s. The accomplishments of our alumni are a testament to the excellence of our science programs: thirteen Grinnell students have been Rhodes Scholars, one of whom—a chemistry major—was the first woman in Iowa to receive this award. In the past seven years, nine Grinnell seniors have received NSF Graduate Fellowships; science graduates have also been awarded Marshall, Howard Hughes Medical Institute, Watson, and Fulbright Fellowships. In 1992, two of the 24 NSF National Young Investigators in chemistry were graduates of Grinnell. Robert Noyce '49 (coinventor of the integrated circuit, co-founding President of Intel and first President of Sematech), Michael Schulhof '64 (President of Sony-USA), and Professor Thomas Cech '70 (University of Colorado and 1989 Nobel Laureate in Chemistry) are among our most illustrious alumni.

Thus, I speak to the issues of NSF reauthorization and budget from the perspective of daily life on a campus that is "science-active"—one that has benefitted significantly from a partnership with NSF. I also speak from my personal experience in mathematics classroom and lab as student and teacher, most recently teaching calculus at Grinnell in a new program, one funded by the NSF.

\* \* \*

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I. A strong undergraduate community serves the national goals of competitiveness and leadership.

I was asked to address the question of *whether the balance between research and education activities at the NSF is correct*, as reflected in the FY96 Budget request. The term "balance" is not one I prefer to use, since it suggests some quantifiable measure, or a sense of competition. I propose that the question be *whether research and education are becoming integrated in a manner that truly serves the national interest*, and that we then ask: what does integrating research and education mean for the capacity of undergraduate SMET programs to contribute to national competitiveness?

The undergraduate sector is the critical link in the national effort to build a productive workforce. Here we prepare the K-12 teachers and the next generation of science professionals, those who will be leaders in corporations and governments, persons who will need a clear understanding of the nature of science and the potential (and limitations) of technology. For most of those who will be the next generation of leaders—among whom will be current students at Grinnell and at colleges and universities across the country—the undergraduate years will be their last formal opportunity for a rigorous intellectual engagement with science and mathematics, engineering and technology.

Colleges like Grinnell, and my ICO colleagues, operate under an implicit contract with our students, with the families of our students, and with the citizens of this nation to provide an education that sends out graduates equipped to lead productive and self-fulfilled lives. When the faculty, administrators, and Trustees at Grinnell reflect on that contract, we know we have to sustain strong programs in science and mathematics if our students are to be well-prepared for their world. Indeed, we know we have to continue to do even better if we are to attract the kind of students who aspire to be leaders into the 21st Century.

As a community we look at how we educate all our students, those with interest in K-12 teaching, those (a growing number) who come to us with a clear sense that a career in one of the scientific or technological fields is right for them, and those students who look toward careers in fields outside of science and technology. We look at what works in getting students interested and involved in the study of science and mathematics. Here is what we found;

- \* hands-on experiences for students, in beginning courses through senior projects;
- \* interdisciplinary, collaborative teams of students and students, students and faculty, faculty and faculty;
- \* networking computers for use by majors and non-majors—interfacing computers and lab equipment;
- \* easy access for all students to the most sophisticated equipment;
- \* courses that connect to the real-life experience of students;
- \* persistent personal contact between faculty and students—in class and, especially, in the lab;
- \* space and time for the serendipitous encounter that is an essential part of doing science; and
- \* facilities that are safe, and that accommodate such an environment for learning.

We found what works is when research and teaching are integrated, when senior professors and newly-appointed faculty are committed to translating their research into learning experiences for students—all students, majors and non-majors, those who aspire to be K-12 teachers and those working toward a career in industry or academe. This has been the culture for many years on our campus, and this is the key reason for the productivity of Grinnell and other ICO institutions.

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Why is this important? Why is integrating education and research, providing hands-on learning opportunities for students—at all levels and with different career aspirations—in the national interest? The answer is clear: we need a workforce for the future with the kind of skills learned through a rigorous encounter with science and mathematics; we need a citizenry prepared to make decisions about issues with scientific and technological dimension. What is most telling, the corporate leaders on my Board of Trustees regularly describe the kind of people they seek to hire: persons who can ask questions, solve problems, and work collaboratively, persons who know how to communicate the results of their work, persons who know how to use computers and other sophisticated equipment.

Such skills are developed when students have the opportunity to "do science" as scientists do science. More and more, what is happening on campuses across the country is that students are being taught how to ask questions, question evidence, and use computers and other sophisticated instrumentation in seeking answers. Many of the innovative courses now being developed for beginning students provide "research-training" opportunities. These courses challenge them to take an active (rather than passive) role in shaping their understanding and to work collaboratively in teams—sharing ideas freely and taking collective responsibility for the results of their work. Many of these students, particularly those who become majors, are actively involved with faculty research projects.

If you were to visit one of our campuses during the academic year or summer, you might see students and faculty working together on NSF-funded projects exploring:

- \* the interaction of the solar wind with the Earth's near-space environment (even traveling to the Arctic Circle to install instrumentation);
- \* the impact of the zebra mussel on indigenous mussels in the St. Croix River; or
- \* the relationship between parasite infestation and cancer incidence in mammalian hosts.

Given in Attachment III are fuller descriptions of these and other current research activities on ICO campuses, activities through which students gain a sense of the wonder and excitement of doing science, and are impelled to continue their learning. Research and education are integrated on our campuses. For us, involving undergraduates in research and research-training is just another way of teaching. Our collective responsibility is to provide such opportunities, at least in a limited way, to all undergraduates.

Increasingly, NSF policies and programs are integrating education and research in creative ways. The new CAREER program, which supports young faculty with demonstrated ability to integrate teaching and research, is one critical pilot program (succeeding a similar program focused primarily on advancing the research careers of young faculty). Another is the new Collaborative Research in Undergraduate Institutions (CRUI) program, which recognizes that the boundaries between the disciplines are dissolving. CRUI supports multidisciplinary research projects that involves undergraduate faculty and students. Each of these new programs should be evaluated; they should be expanded. (CRUI received about 330 applications, and will be making only 20 awards. Demand outstrips supply!) Through programs like these, NSF sends signals to the community that faculty who spend time with students, integrating research and educational activities, will be rewarded at the national level.

Support for such activities fits precisely into the NSF mandate, to invest in research and education in all aspects of science, mathematics, and engineering. Research done with undergraduates, although it may not be done at the speed as when post-docs and Ph.D.'s are solely involved, does advance the discovery and integration of knowledge. Thus, when it is done right—when research and education are truly integrated—you get "two for the price of one" creating new knowledge and giving students the skills to succeed in life. Is not this just the kind of effectiveness and efficiency we are all seeking to achieve?

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II. NSF and the nation's colleges and universities have a shared responsibility to build and sustain undergraduate programs in science and mathematics that serve the national interest.

Grinnell and my sister institutions could not have done what has been completed so far, and will not be able to finish what is planned, without many partners—friends of the college (individuals and private foundations); without the financing opportunities provided by state and local governments; and without the important leveraging support from the National Science Foundation. NSF grants to the undergraduate community set the standards for our work in research, research-training, and education; they provide further incentive to colleges like mine by helping to set the parameters for effective planning for curriculum and facilities renewal; they leverage critical dollars from other donors, and they enable us to make a significant contribution to the community.

A question was asked at last week's Hearing about possible duplication between federal agencies in programs that support science and mathematics education. This is a critical question, at a time when every budget line item is being examined (on campuses as well as in Congress). I will answer it from the perspective of the undergraduate community. Attachment IV gives data from the 1992 FCCSET study, which identifies NSF as the nearly sole source of support for undergraduate programs. If we are to build and sustain the strong undergraduate SMET community this nation needs, NSF is the key to making this happen. It is important to note here that, even given the significant increase in funding for education at NSF over the recent past, funding levels for undergraduate programs has been relatively flat.

NSF support for instrumentation, for course and curriculum development, for facilities, for partnerships and for faculty development is critical to the capacity of undergraduate institutions to continue to serve the national interest. This is a public policy issue, and should be considered just as carefully as issues about the balance between curiosity-driven and strategic research. Budget justifications within the Research Directorates in the NSF FY 1996 Request describe how the Foundation is the nation's principal supporter of fundamental academic research. This is the same case we must make for the undergraduate sector.

At this point I would like to address the question: *what level of funding should be provided to the academic research facilities modernization program?* My answer will be: the level of funding in the original authorization of the Academic Facilities Infrastructure (ARI) Program—\$250 million.

The physical environment for research and research-training on our campuses is in a crisis situation, a crisis at three levels. First, many buildings are deteriorating, structurally inflexible, and obsolete. Many need to be brought up to standards for health and safety. Many need to be renovated to accommodate computer networks and other sophisticated technologies that are now an integral part of the undergraduate experience. Second, the generation of facilities now in use were designed for passive learning, for spoon-feeding bits of information into students, for a learning environment where the faculty member was "in control." I described earlier *what works*. To have programs that work requires spaces that accommodate the active, collaborative, community-based approach to learning. The final dimension of the crisis is the present fiscal climate. To do SMET education right is costly; it will be more costly for the nation over the long-term if we do not do it right.

It is important not to lose sight of the fact that we are not asking NSF or the federal government to meet all our needs, not even most of them; we are asking for a partnership that works together to find new ways of financing infrastructure needs, working together on a national agenda.



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There are significant strengths of the current ARI program, as authorized, that I must emphasize:

- \* As mandated by Congress, it provides support in an equitable fashion to institutions large and small, public and private, in all parts of the country.
- \* It sets national standards for planning, helping to ensure that the current generation of facilities will serve the community well into the next century.
- \* It is a grassroots program, in that institutions identify their own priorities.
- \* It is a merit-review process, not a pork-barrel program. The best projects get funded.

Although not explicit in the authorization language, one valuable dimension of the program has been that it exists at all. Planning new spaces (new construction or remodeling projects) takes about three-five years. In my case at Grinnell, beginning in 1991 through the projects currently underway, we will have committed \$14.5 million to modernizing facilities for science and mathematics programs. Bringing together the resources to make this happen was a difficult task; the NSF grant we got early on was a significant catalyst, leveraging the further support needed to complete the project. I have reviewed the ARI awards lists since the program began; many members of this Subcommittee have institutions in your district that have applied for and received ARI grants. To be successful, they, like Grinnell, had to develop a comprehensive scheme for planning and fund-raising that incorporated the possibility of NSF ARI funding. We could manage our affairs more effectively because of the partnership with the NSF.

A discussion about the need for a coherent national plan for renewing the infrastructure for research and research-training at the undergraduate level brings us to the first recommendation I wish to place before this Subcommittee, that in the process of reauthorization:

- \* The Subcommittee direct the National Science Board to establish a Special Commission to outline a formal plan of action and a five-year agenda (into the 21st Century) for all science, mathematics, engineering, and technology (SMET) activities within the Foundation that affect students and faculty, programs and facilities at the undergraduate level.

The primary reason we make this recommendation is, if this sector is to continue to serve the national interest in a changing world, we need to know more than we now know about the present and future circumstances for undergraduate SMET programs.

We need to know about:

- \* **The scope of the facilities problem.** Currently, surveys to determine the nation's facilities needs are designed largely for research-intensive universities, extrapolating from that data the needs of predominantly undergraduate institutions. We welcomed the language in the recent reauthorization bill that directed NSF to design surveys to gather precise and useful information about predominantly undergraduate institutions. We hope such language is included in the current reauthorization bill. It may be that the 10 billion dollar price tag for facilities modernization is a gross underestimate; it may be that there are ways to leverage public and private funds to provide safe and educationally-sound facilities for teaching and learning in SMET programs at the undergraduate level. We need to know.
- \* **Our students.** Already reforms at the K-12 level are having a significant impact at the undergraduate level; this impact will be even more noticeable in the coming years, as elementary and secondary students experience hands-on science, as standards for world excellence in science and

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mathematics are set and met. Just as some students are becoming more scientifically-literate, others come to our campuses under-prepared for college-level study. This suggests that NSF give continued and expanded attention to the reform of introductory courses, so they are pumps, not filters. To know *who our students are* will take the kind of cross-sector partnerships now fostered by NSF's systemic initiatives; to transform introductory courses will take a larger number of smaller grants to individual campuses. What is the right balance here? We need to know.

\* **Our faculty.** The challenge, particularly in a time of limited resources, is to develop the right set of programs that support faculty at different career stages, and programs that recognize and reward faculty actively integrating research and education, that encourage faculty to move into new interdisciplinary areas. What do we know about the age, disciplinary experience and expertise of our faculty, about their departmental situations, that would ensure that the present set of NSF opportunities for faculty scholars is what is needed? Should the new CAREER program and the new CRUI program be expanded? Should there be increased opportunity for faculty to connect what they do in lab and what they do in classroom? Do we have appropriate mechanisms in place to recognize and reward faculty taking the lead in transforming the classroom? We need to know.

\* **The changing nature of science and technology.** I hope you are as enthusiastic as I am about the level of research that is being done by students and faculty at the undergraduate level (see above). If you were to come to Grinnell, you would see students working with a member of our physics faculty on developing new techniques to make more practical superconductors which can operate in high magnetic fields, or with a member of our biology faculty on understanding how genes needed for DNA repair are turned on and off, specifically in response to DNA damage. Research of this level and character is possible because of the instrumentation now available. Are we taking maximum advantage of available technologies, particularly information technologies, in undergraduate programs? Do the changes now underway truly reflect the increasingly interdisciplinary nature of science? Would a comprehensive grant, one that required institutions to present a coherent plan for renewal of program, faculty, and facilities be more appropriate today than the smorgashbord of programs now within NSF? We need to know.

\* **The changing societal context.** In past years, programs and policies, at NSF and on our campuses, were determined primarily based on the need to produce the next generation of Ph.D.'s. We have a more complex set of goals now, reflecting the complexity of society, and the increasing impact of science and technology on all aspects of life. Our undergraduate programs must now be focused more directly on preparation and enhancement of K-12 teachers if our society is to achieve the goal of world excellence in science and mathematics for elementary and secondary students. Our programs have been challenged to prepare the workforce of the future with the skills to be productive in a technological world, and to provide all students with the insights and capacities to make decisions required of citizens in a democracy. We have been challenged to ensure that all students, particularly women and ethnic minorities currently underrepresented in science and mathematics, are given the opportunity to succeed.

What do our schools, our industries, our political system require? As Lewis Thomas said, "We need to know science, more science." How do we go about this in the most effective manner? We need to know.

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We also need to know how the current and proposed NSF programs, targeted at students and faculty, facilities and institutions at the undergraduate level, fit together into a coherent whole. We need to know if the Boards and Panels that provide advice and counsel to NSF are representative of the broader community it seeks to serve? We have a partnership between the National Science Foundation and the colleges and the universities of this country that has proven to be successful in years past. As we look toward the future, we should come to a new agenda, one that is based on a grassroots understanding of what needs to be and how to achieve some mutually-agreed upon goals.

May I bring to the attention of this Subcommittee the most recent issue of *Foundations for the Future—Turning Points*, a publication of the Education and Human Resources Directorate at the National Science Foundation. This issue, which talks about the impact of NSF on people, features Tom Cech on the cover. The article quotes Tom as remembering "...his NSF Graduate Fellowship as the vehicle that gave him the spirit of independence that continues to influence his life." In this publication you will find engaging stories about students and teachers whose lives have been changed by a NSF grant, and how each of these individuals are changing the lives of other students and teachers—and making our world a better one. Each of these stories talk about getting students, at all levels, to ask important questions, to work with each other, and to teach themselves." This publication documents the contribution that NSF has made to this country since it was founded 50 years ago.

My final recommendation: As this Subcommittee and your Congressional colleagues wrestle with where to get the best return—short-term and long-term—on an investment in infrastructure for the future of this country, supporting education, research-training, and research at the undergraduate level will be your best bet.

As this Subcommittee considers issues about the mission, aims and objectives for NSF into the 21st Century, we urge you to keep in mind that a strong National Science Foundation is absolutely central to our nation's continued economic success, and to our continued capacity to enable all citizens to achieve their greatest potential—through education and through work, and through the discovery, integration, dissemination, and employment of new knowledge in service to society.

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#### ATTACHMENT I.

- \* UNDERGRADUATE ORIGINS OF EARNED PH.D.'S
- \* SCIENCE AND BACCALAUREATE DEGREES AS PERCENTAGE OF UNDERGRADUATE ENROLLMENTS

#### ATTACHMENT II.

- \* EXCERPTS FROM *SCIENCE*,  
 Innovations on Campus. Volume 266, 4 November 1994

Descriptions of programs on ICO campuses:

1. Page 250. Some Small Schools are Big on Manufacturing Scientists.  
 (St. Olaf College, Grinnell College, Reed College, Carleton College, Pomona College, and Oberlin College)
2. Page 856. Assault on the Lesson Plan.  
 (Reed College and Dickinson College)
3. Page 858. Curricula Reform Hits the Web.  
 (Gettysburg College)
4. Page 875. New Modes for Making Scientists.  
 (Dickinson College, College of the Holy Cross, Oberlin College)
5. John Jungck: Godfather of the Virtual Bio and Genetics Labs  
 (Beloit College)

#### ATTACHMENT III.

- \* DESCRIPTION OF SELECTED RESEARCH/EDUCATION ACTIVITY-ICO CAMPUSES

#### ATTACHMENT IV.

- \* FCCSET STUDY OF FEDERAL SUPPORT FOR UNDERGRADUATE SMET PROGRAMS

#### ATTACHMENT V.

- \* EXCERPTS FROM *FOUNDATIONS FOR THE FUTURE*, NSF Publication

Undergraduate Origins of Earned Ph.D.'s  
in Scientific Fields  
1983-1992

Rank (1994 Carnegie: Res, Doc, Mast, Bacc, Engr)	Institution Name	Class - 1994	Con- trol	State Code	Tot BA's 75-84	Sciences and Mathematics	
						N	%
1	California Institute of Technology	Research I	Priv	CA	1,860	410	22.04%
2	Harvey Mudd College	Engineering	Priv	CA	975	176	18.09%
3	Reed College	Baccalaureate I	Priv	OR	2,218	195	8.79%
4	Massachusetts Institute of Technology	Research I	Priv	MA	11,018	886	8.04%
5	University of Chicago	Research I	Priv	IL	5,433	423	7.79%
6	Carleton College	Baccalaureate I	Priv	NH	3,873	289	7.46%
7	Swarthmore College	Baccalaureate I	Priv	PA	3,061	176	5.75%
8	Haverford College	Baccalaureate I	Priv	PA	2,208	116	5.25%
9	Kalamazoo College	Baccalaureate I	Priv	MI	2,793	144	5.16%
10	Pomona College	Baccalaureate I	Priv	CA	3,195	162	5.07%
11	New Mexico Institute of Mining and Technology	Engineering	Pub	NM	1,289	60	4.65%
12	Johns Hopkins University	Research I	Priv	MD	6,862	311	4.53%
13	Grinnell College	Baccalaureate I	Priv	IA	2,796	123	4.40%
14	Princeton University	Research I	Priv	NJ	10,542	461	4.37%
15	Harvard University	Research I	Priv	MA	17,751	736	4.15%
16	University of California-San Diego	Research I	Pub	CA	13,298	531	3.99%
17	Bryn Mawr College	Baccalaureate I	Priv	PA	2,353	93	3.95%
18	Wabash College	Baccalaureate I	Priv	IN	1,696	65	3.83%
19	Oberlin College	Baccalaureate I	Priv	OH	6,392	239	3.74%
20	Rice University	Research II	Priv	TX	6,764	247	3.65%
20	University of Rochester	Research I	Priv	NY	10,350	378	3.65%
22	Yale University	Research I	Priv	CT	12,575	437	3.48%
23	Bates College	Baccalaureate I	Priv	ME	3,127	107	3.42%
24	Earlham College	Baccalaureate I	Priv	IN	2,199	75	3.41%
25	Cornell University	Research I	Priv	NY	30,262	973	3.22%
26	Case Western Reserve University	Research I	Priv	OH	6,903	221	3.20%
27	Rensselaer Polytechnic Institute	Research II	Priv	NY	9,502	301	3.17%
28	College of Wooster	Baccalaureate I	Priv	OH	3,893	119	3.06%
29	Marlboro College	Baccalaureate I	Priv	VT	400	12	3.00%
30	Junata College	Baccalaureate I	Priv	PA	2,527	75	2.97%
31	Beloit College	Baccalaureate I	Priv	WI	2,418	70	2.89%
32	Brown University	Research I	Priv	RI	12,893	370	2.87%
33	St. John's College	Baccalaureate I	Priv	MD	770	22	2.86%
34	Long Island University Southampton Campus	Master's II	Priv	NY	2,283	64	2.80%
34	University of California-Davis	Research I	Pub	CA	28,576	801	2.80%
36	Bowdoin College	Baccalaureate I	Priv	ME	3,310	92	2.78%
37	Whitman College	Baccalaureate I	Priv	WA	2,204	61	2.77%
38	Dope College	Baccalaureate I	Priv	MI	4,411	121	2.74%
39	Muhlenberg College	Baccalaureate I	Priv	PA	3,560	96	2.70%
39	Williams College	Baccalaureate I	Priv	MA	4,666	126	2.70%
41	Dartmouth College	Doctoral II	Priv	NH	9,858	263	2.67%
42	Franklin & Marshall College	Baccalaureate I	Priv	PA	4,794	127	2.65%
43	Amherst College	Baccalaureate I	Priv	MA	3,714	98	2.64%
44	Wesleyan University	Baccalaureate I	Priv	CT	5,513	145	2.63%
45	Knox College	Baccalaureate I	Priv	IL	2,292	60	2.62%
45	Stanford University	Research I	Priv	CA	16,702	438	2.62%
45	University of California-Riverside	Research II	Pub	CA	7,946	208	2.62%
48	Davidson College	Baccalaureate I	Priv	NC	3,054	79	2.59%
48	Mount Holyoke College	Baccalaureate I	Priv	MA	4,943	128	2.59%
50	Allegheny College	Baccalaureate I	Priv	PA	4,035	104	2.58%
50	University of California-Santa Cruz	Research II	Pub	CA	12,325	318	2.58%
52	University of California-Berkeley	Research I	Pub	CA	52,343	1,314	2.51%
53	Occidental College	Baccalaureate I	Priv	CA	3,708	92	2.48%

# Science & Baccalaureate Degrees As Percentage of Undergraduate Enrollments

Academic Institution	State Type (C7)	Carnegie	Enrollment		Baccalaureate Degrees as a Percentage of Enrollment									
			Undergrad	FT & PT	Students	Chemistry	Physics/Astro	Earth	Health	Biotech				
			Fall '92		89-92	89-92	89-92	89-92	89-92	89-92				
Pomona College	CA	LA1	1,493		15.3%	1.7%	2.7%	0.5%	4.2%	6.2%				
Scripps College	CA	LA1	616		2.6%	0.0%	0.0%	0.0%	0.0%	2.6%				
University of California-Berkeley	CA	R1	21,707		13.6%	1.3%	1.2%	0.3%	1.9%	9.5%				
University of Redlands	CA	C1	3,130		2.7%	0.5%	0.2%	0.0%	0.8%	1.2%				
Colorado College	CO	LA1	1,920		18.4%	2.0%	2.7%	1.2%	2.1%	10.4%				
University of Colorado at Boulder	CO	R1	22,027		6.3%	0.6%	0.5%	0.2%	1.2%	3.7%				
Coe College	IA	LA1	1,201		7.4%	0.8%	0.5%	0.0%	1.5%	4.6%				
Cornell College	IA	LA1	1,162		11.9%	1.1%	0.6%	1.8%	1.5%	6.6%				
Grinnell College	IA	LA1	1,275		24.8%	4.9%	3.1%	0.0%	6.6%	10.2%				
University of Iowa	IA	R1	18,804		4.6%	0.4%	0.3%	0.2%	1.3%	2.5%				
Knox College	IL	LA1	955		13.9%	6.5%	1.6%	0.1%	2.2%	8.5%				
Lake Forest College	IL	LA1	959		10.5%	2.7%	1.3%	0.0%	1.8%	4.0%				
Monmouth College	IL	LA2	564		15.9%	2.2%	2.2%	0.7%	4.3%	6.5%				
University of Illinois at Urbana-Champaign	IL	R1	27,548		9.8%	1.1%	0.3%	0.2%	1.9%	6.5%				
Manchester College	IN	LA2	1,044		4.3%	0.5%	0.9%	0.6%	1.9%	2.4%				
Purdue University, Main Campus	IN	R1	31,199		3.9%	0.5%	0.3%	0.2%	1.0%	1.0%				
College of the Holy Cross	MA	LA1	2,767		13.4%	2.7%	1.4%	0.0%	4.5%	5.0%				
Massachusetts Institute of Technology	MA	R1	4,520		23.0%	2.4%	6.2%	1.0%	5.4%	7.7%				
Colby College	ME	LA1	1,781		15.6%	1.9%	0.8%	1.2%	1.9%	9.8%				
University of Maine at Orono	ME	R1	10,204		3.0%	0.2%	0.1%	0.0%	0.6%	2.0%				
Hopkins College	MI	LA1	2,751		13.0%	3.0%	0.8%	0.7%	1.8%	6.0%				
Calumet College	MI	LA1	1,232		16.3%	3.8%	2.4%	0.0%	1.6%	5.5%				
University of Michigan at Ann Arbor	MI	R1	22,234		8.4%	0.7%	0.5%	0.1%	1.6%	3.1%				
Augsburg College	MN	C2	2,781		4.1%	1.1%	0.8%	0.0%	1.2%	1.3%				
Carleton College	MN	LA1	1,834		21.3%	4.5%	4.3%	3.4%	2.7%	6.4%				
College of Saint Catherine	MN	C2	3,292		3.2%	0.9%	0.0%	0.0%	0.5%	1.0%				
Macomber College	MN	LA1	1,638		11.7%	1.5%	1.2%	0.7%	4.1%	4.2%				
Saint Olaf College	MN	LA1	3,015		25.8%	4.8%	1.3%	0.0%	9.7%	10.6%				
University of Minnesota at Twin Cities	MN	R1	41,604		4.4%	0.3%	0.4%	0.2%	1.3%	2.2%				
Dartmouth College	NH	LA1	2,865		15.7%	1.9%	1.1%	0.3%	1.9%	10.0%				
Duke University, Main Campus	NC	R1	34,955		3.5%	0.4%	0.3%	0.1%	0.7%	2.0%				
Ohio Wesleyan University	OH	LA2	1,932		7.8%	1.0%	0.8%	0.3%	1.3%	4.3%				
Orion State University	OH	R1	11,475		6.3%	0.6%	0.4%	0.0%	1.1%	4.1%				
Reed College	OR	LA1	1,208		24.5%	4.5%	5.5%	0.3%	4.0%	10.5%				
Attorney College	PA	LA1	1,782		18.0%	3.3%	2.0%	0.6%	3.7%	8.4%				



# SCIENCE

## Innovations on Campus

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**T**he U.S. system of higher education has, over the decades, produced a cadre of researchers that is the envy of the world. Thousands of young people across the globe struggle annually to obtain student visas permitting them to submit themselves to the "Great American Doctorate Factory." And yet this esteemed resource has come under fire of late from above and below.

Corporate executives, congressional representatives, and even many eminent scientists have called for change. In this issue, Commerce Department Undersecretary for Technology Mary Lowe Good, previously vice president for research at Allied-Signal Corp., and National Science Foundation Director Neal Lane, former provost of Rice University, team up in a provocative Policy Forum (p. 741). It is no longer a given that the "academic research and education enterprise" should be primarily devoted to producing "superbly capable and highly specialized students prepared to carry on in the traditions of academic basic research," they argue. If, instead, society's goal might be to produce versatile scientists and engineers able to work in groups and "meet the needs of industry and other sectors, then there is virtual consensus that the current system leaves room for improvement."

Meanwhile from below, complaints filter upward from the young: Traditional courses, some will tell you, don't prepare them for the real world, and traditional teaching methods don't engage their attention. The world has changed, many say, and their universities haven't.

But this is only partially correct. This special section of *Science* celebrates seeds of change being sown across the United States. In small and large schools alike, individual teachers are developing innovative curricula—and novel pedagogical techniques as well—to address the problems created by disaffected (and fearfully underprepared) undergraduates. Programs are sprouting on the graduate level—and even in some undergraduate settings—that bring the real world of interdisciplinary and applied research onto campus or take the student into a corporate lab to do productive research. And, increasingly, the wise heads in scientific societies are sponsoring colloquia to discuss wholesale reforms of the system that trained them so brilliantly.

But all the attention we give to novel educational approaches shouldn't detract from the many brilliant teachers teaching in traditional fashions or the successful programs that already exist. Neither are we suggesting that educational reform, as we have described it, is limited to the United States.

This year, we asked a dozen reporters throughout the United States to interview a score each of students, assistant professors, tenured professors, and department chairs at elite and not-so-elite schools. We wanted to know what they found most worrisome and what most needed to be changed in the way our scientists are being made. Next year, we will expand our inquiry across Europe and into Asia. Write us. Tell us what we've missed and where we've hit a nerve. Your letters will improve our future special reports.

—Ellis Rubinstein

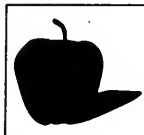


Photo Research: Anna Alvarez; Illustrations: Diane DeFrancesco



## Some Small Schools Are Big On Manufacturing Scientists

When science students at St. Olaf College, a small college in Northfield, Minnesota, feel overwhelmed, help seems omnipresent. Faculty are not only present in the lab, for example, but students who fall behind often get the chance to separate lab work from the lecture portion of the course. "I couldn't have handled p-chem lab and lectures together," acknowledges Amy Roos, a St. Olaf graduate now doing advanced work in theoretical chemistry at Northwestern University. "So my faculty adviser suggested that I take the lab a year later." Even its introductory lecture courses allow for feedback during or immediately after class.

Is such concern unique to the Midwest, or to schools without lofty reputations? Hardly. Jim Quallen, a chemistry major at the California Institute of Technology (Caltech), also knows where to turn when things get harried. "This is a small school, and you can always find someone who's already taken the course you're having trouble with," he says.

"Also, the professors are understanding about extending deadlines. The students work hard and the faculty try to accommodate us."

While St. Olaf and Caltech may differ in many ways, what they have in common is their small size. And that quality pays enormous dividends to science. When the U.S. Office of Technology Assessment tracked baccalaureate graduates who won their Ph.D.s between 1950 and 1986, it discovered that small colleges like Caltech and St. Olaf, per capita, yielded more Ph.D.s than most large schools. Last year, a study by the Higher Education Data Sharing Consortium in Lancaster, Pennsylvania, came to the same conclusion: Starting with Caltech and the Massachusetts Institute of Technology (MIT), the list of institutions that graduate the highest percentage of students who go on to receive doctorates in science and engineering includes the University of Chicago; Reed, Swarthmore, Carleton, Pomona, Haverford, and Oberlin colleges; and Princeton University. Only Chicago, Princeton, and MIT have undergraduate student bodies that exceed 2500, with Princeton the largest at 4600.

What makes these places—many of which are known as liberal arts schools—produce such a rich diet of scientists? The answer, at first, may seem counterintuitive: Most of these schools are principally dedicated to the training of ... undergraduates. "Everything that happens here is because of undergraduates," says Reed chemist Arthur Glasfeld. "They are the focus for the entire energy of the faculty."

The consequence, say educators, is a bond between faculty and students that works better than size and power. "Mentoring, mentoring, mentoring is what we do well," says Wellesley chemist Adele Wolfson. "The absence of graduate students is a positive influence on the attention our undergraduates receive."

Introductory courses in small schools typically enroll only

30 to 100 students—a pittance compared to what most freshmen must endure. More advanced courses often contain fewer than a dozen students. Glasfeld says, "I know every student in the introductory chemistry course and every junior and senior chem major."

The second big advantage of many small schools may again at first seem counterintuitive: Although big schools can afford fancier facilities, small schools often offer more hands-on research experience. "At large universities, only the most assertive get research opportunities," explains St. Olaf biologist Kathleen Fishbeck. "We have solid B and B+ students who, if they get the chance, can excel in the lab. At large schools they would be lost."

What's more, students are more likely to be able to pursue a project of their choice, "instead of being a cog in the research machinery of their supervisor," says Glasfeld. And they don't

have to play second fiddle to grad students in gaining access to lab equipment. At Reed, for example, undergrads use automatic x-ray diffraction and nuclear magnetic resonance equipment, plus a variety of lasers—apparatuses that would make most small and midsized universities proud.

It's worth noting that small size doesn't necessarily mean poverty, too. Grinnell and Swarthmore colleges—each with only about 1250 students—have endowment of more than \$400 million, with a per capita figure higher than that at Harvard or Yale universities. And less fortunate schools are savvy about winning grants from organizations that support undergraduate education, such as the National Science Foundation, the Howard Hughes Medical Institute, the Pew Charitable Trust, The Research Corporation, and the Keck, Noble, Mellon, Ford, and McKnight foundations. "We have had to work very hard to get funds to support our undergraduate

instruction," says St. Olaf chemist Gary Meissler. "But that's what smaller schools do."

To be fair, even well-financed small schools have some liabilities—among them, fewer course offerings and smaller libraries. And then there's tuition and fees—as much as \$25,000 a year compared with \$6000 for a large, state-supported school. Faculty members at small schools acknowledge making personal sacrifices to sustain their commitment to teaching. Glasfeld, for example, studied structural enzymology at Harvard and MIT; now, he says, most of his research is done during the summer because "only cracks of time" are available for such work during the academic year.

But that trade-off may benefit tomorrow's scientist. And Glasfeld speaks for thousands of his colleagues at small undergraduate institutions when he says he wouldn't trade places with a colleague at a major research university. "I always knew I wanted to teach," he says. "At Reed I get rewarded to teach."

—Anne Simon Moffat

### But Caveat Emptor for Small Grad Schools



William Bowen

While small may be beautiful in teaching science to undergraduates, it is not so good for training graduate students. Very small programs lack the critical mass to do the job well, says economist William Bowen, president of the Andrew W. Mellon Foundation and co-author, with Harvard president Neil Rudenstine, of *In Pursuit of the Ph.D.* Bowen says there's been "an excessive proliferation of Ph.D. programs that graduate only a few students each year." The trend is fueled by the status associated with operating a doctoral program. The problem, according to Bowen, is that programs granting fewer than four Ph.D.s a year often fail to offer top-quality training. In addition, they draw time and talent away from undergraduate teaching. Although Bowen is equally critical of graduate programs so large that students become lost in them, he believes that some universities would be wise to offer fewer graduate programs, or none at all in the case of predominantly undergraduate institutions.

He also practices what he preaches. A graduate and trustee of Denison University in Granville, Ohio, he offers straightforward advice whenever the discussion turns to broadening the school's academic portfolio. "I tell them to continue to do what they do so well, teach undergraduates."

—A.S.M.

## Assault on the Lesson Plan

**Courses are being revamped, and novel programs created, as U.S. science faculty try to capture the MTV generation**

At Washington University in St. Louis, biologist George Johnson teaches a course on the biology of dinosaurs. His goal: To increase the interest of non-science majors in his favorite field. At the University of Wisconsin in Madison, chemistry professor Arthur Ellis is restructuring courses he had taught for 14 years to highlight the latest research in materials science. His objective: To show the chemists of tomorrow that the discipline's stodgy reputation doesn't preclude a chance to discover new vistas. And at Brandeis University in Waltham, Massachusetts, Lawrence Abbott teaches computer modeling of heartbeat rhythms and the progression of disease through a population (p. 869). His hope: To show even the most computer-illiterate undergrads that off-putting mathematical models can track real-world phenomena.

Across the United States, university science faculties are starting to realize that traditional curricula no longer do the job and that radical changes are needed in what and how undergraduate students are taught. Biology graduate students are being told to emulate medical-school students by rotating through research laboratories rather than remaining in one area for their entire graduate careers. Entire departments—such as the chemistry department at the University of Michigan—are reworking their offerings to make them fit together better. Traditional disciplines are recognizing that they must introduce other disciplines—for example, every physics major at the Massachusetts Institute of Technology must now take at least one introductory course in biology. And new communication channels—from electronic mail to annual conferences for innovators—are allowing would-be reformers to incorporate the successes and avoid the failures of others.

Indeed, big money is flowing into curricula reform, principally from the National Science Foundation (NSF) and the Howard Hughes Medical Institute (HHMI). Efforts to reform curricula and teaching methods in college-based science education received \$18 million of NSF's \$81-million budget last year for improving undergraduate education. HHMI has put \$63.9 million over 5 years into reforming biology programs, including programs to help schools upgrade their teaching labs, and may spend even more next year.

But for reforms to succeed and spread to other schools, reform-minded faculty members must breach some formidable barriers.

"There have been waves of reform efforts since the 1950s," says Arnold Arons, a professor emeritus of physics at the University of Washington in Seattle and veteran of past battles. "But the question is whether they can last." Few do, he believes. Why not? Arons and others point to such obstacles as tenure policies that promote faculty research over teaching, an unwillingness by faculty members to change how as well as what they teach, and resistance to reforms developed at other schools.

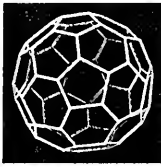

### Facing facts

One hopeful sign of permanent change is the growing desire among faculty members to instill in students the critical thinking skills necessary for life as a scientist. "A lot of curricula just want you to memorize facts and repeat them on multiple-choice exams," says New York University neuroscientist Lynn Kiorpes, who heads NYU's new undergraduate neuroscience program. "But science is using what you know to solve a problem."

Science also must be more than a history lesson, says John Rigden, the director of physics programs at the American Institute of Physics. First-year physics courses taught as a chronology of the progress of physics from Newton's mechanics to Maxwell's electrodynamics and Einstein's relativity not only turn students off, he says, but they also rarely teach the present. The result, says Rigden, is that "a student taking introductory physics is left with a picture of physics in the 1880s. Yet we tell students that 20th-century physics is the most exciting part."

So what are reformers after? Says Linda Mantel, dean of faculty and a biology professor at Reed College in Portland, Oregon: "We want to devise ways to teach problem-solving skills to people who want to be prob-

lem solvers." To achieve this goal, reformers are abandoning "plug and chug" curricula that emphasize how to read problems, figure out which equation applies, plug in given variables, and churn out the correct answer. In their place are courses that boost students' critical thinking skills. At Dickinson College in Carlisle, Pennsylvania, physics professor Priscilla Laws allows students to investigate physics phenomena such as friction and momentum rather than listen to lectures. At Trinity University in San Antonio, Texas, computers permit biology students to go beyond simply identifying cells to investigating how they interact and

Innovative Curricula	
Introducing undergrads to hot fields	 
Developing interdisciplinary majors	
Preparing for alternate career tracks	
Encouraging undergrads to do hands-on research	

function. "These students are creating data sets on problems that have never been looked at before," says Trinity biology professor Robert Blystone.

Another common goal for reformers is to incorporate the latest research into the curriculum. Success can turn an introductory biology course replete with the dates of Darwin's voyages on the HMS Beagle into an exploration of how to manage an ecosystem to preserve biodiversity. "We want [students] to see right away how some of the courses they will be taking fit together to address everyday concerns," says Daniel Udovic, chair of the biology department at the University of Oregon, which recently added a series of freshman seminars on topics such as the biology of the timber crisis and the genetics revolution.

Reformers are also placing renewed emphasis on interdisciplinary and interdepartmental courses to show students how several lines of research can be brought to bear on the same topic. At NYU, faculty members from seven departments joined 2 years ago to create a neuroscience major for undergraduates. Topics range from the molecular biology of synaptic communication between nerve cells to the behavioral aspects of neurological diseases such as schizophrenia and Alzheimer's. And at California State University, Los Angeles, students in ecology, chemistry, and biostatistics jointly study such environmental problems as toxicity levels of DDT in local fish.

At the same time students are learning how science relates to the real world, they are also getting a taste for the way science is practiced. "The hands-on work teaches them to think like scientists," says chemistry professor Leroy Wade of Whitman College in Walla Walla, Washington. Since 1978, the number of science undergraduates involved in research has jumped from a few percent to almost a quarter of those enrolled in science courses, says chemistry professor Michael Doyle of Trinity University, where every chemistry major is required to perform undergraduate research.

These changes are not confined to undergraduate courses. Graduate schools, in response to the long-running criticism that Ph.D.s are trained too narrowly, have begun to offer degrees in interdisciplinary fields, such as molecular and cellular biology and materials science, and to put greater emphasis on careers in industry. At the University of Texas at Dallas, for example, chemistry graduate students must complete a year-long practicum with local industry. And at North Carolina State University in Raleigh, scientists with as little as a master's degree are working with business grad students to form high-tech start-ups that can commercialize university research (p. 865).

Despite high hopes for such novel programs, critics warn that the lofty goals for reform have been sounded many times before. In a speech given last fall to directors of innovative programs, University of Arizona biologist Samuel Ward reminded his colleagues that the most common characteristic of curriculum reform efforts is amnesia. As proof, he hauled out three reports—spaced 30 years apart and spanning much of the century—all recommending such changes as boosting stu-



dents' reasoning rather than memorization skills, harmonizing courses with everyday problems, and emphasizing future problems to be solved. Much to its chagrin, the audience was unable to date any of the reports.

#### Big hurdles

There are many reasons for the failure of curriculum reform, say critics, but the most obvious is a lack of money. The computer stations alone for an introductory physics course at Dickinson College called "Workshop Physics"—where students work together in groups of four—cost up to \$2600 apiece. As many as 1300 students attend such introductory courses at large state universities, making the Dickinson model expensive to emulate. Even if the changes are affordable, there's no guarantee they'll become widely used, says Sheila Tobias, a social scientist who has written widely on science curriculum reform. "University professors value their autonomy as teachers," says Tobias. When Brandeis University faculty recently tried to integrate the school's biology, physics, and chemistry curricula, for example, consensus was elusive. "There are [faculty members] who think there is a logic to the current courses and that you just can't muck with it," says Brandeis University biologist John Lisman. The bottom line, says NSF's undergraduate education chief Robert Watson: "You can't tell faculty what to teach."

A final barrier to change is institutional. Opening labs to undergraduates requires that faculty spend more time with students. But there is little incentive to do so as long as faculty tenure continues to be based primarily on research achievements. "If the institutions ignore the reward system and don't support their faculty [who develop new science curricula], then faculty are likely to backslide," says Herb Levitan, NSF's head of undergraduate curriculum development.

#### Making changes stick

Faced with these obstacles, reformers downplay the likelihood of reforms spreading throughout the country's more than 3000 colleges and universities. "Systemic reform is not even the goal here," says NSF's Watson. Curricular change, he says, must begin in the hearts and minds of individual faculty members. Institutions can fund novel programs and spread information about what works, but that doesn't guarantee success. "You take the changes where you can," agrees Stephen Barkanic, who doles out curriculum development grant money for HHMI. "After a while, you hope

**Actions, not words.** Physicist Priscilla Laws (left) hopes to have a more lasting effect on students than the century's worth of curricula reform displayed by biologist Samuel Ward (above).

**"We want to devise ways to teach problem-solving skills to people who want to be problem solvers."**

—Linda Mantel

## New Modes for Making Scientists

**Techniques, materials, and even the core philosophies of pedagogical engagement—all are in flux**

As a tentative prelaw student at Dickinson College in Carlisle, Pennsylvania, Jake Hopkins heard that introductory physics was a good way to satisfy the college's science requirement. He knew he'd have to compete for grades against science majors required to take the course, but he gambled on the favorable buzz and signed up. He guessed right.

On day one, Hopkins learned mechanics by throwing baseballs; later, he learned about electricity by building a stopwatch from wires and circuits, all in a most unusual atmosphere. "That class wasn't competitive like regular science classes," he recalls. "Students worked together, and you could figure things out, not just try to absorb them while they were thrown at you." The professor, Priscilla Laws, was rarely at the head of the class; she was more likely to be found helping teams of students decide which variables to graph next on their computers. Call it Laws' Law of Pedagogy: Don't lecture, coach.

Although she hasn't given a formal lecture in years, Laws' innovative technique in what she calls "Workshop Physics" has won a pile of prestigious awards. Students such as Hopkins—now a junior physics major—are one reason why. "Everything was hands-on," he points out, "and I really liked that approach, because I always understand something once I do it."

Workshop Physics is one example of a growing movement to improve not only what students learn in science class, but how they learn it. Aided by recent educational research, plus large grants from government and private foundations, science faculty around the country are running a rich mix of pedagogical experiments, especially in introductory classes. Professors are transforming lecture halls into learning crucibles, melting the barriers between lecture and lab, and letting students take the lead in shaping their education. Says noted science education analyst Sheila Tobias of the Research Corporation in Tucson, Arizona: "I've never seen such ferment, enthusiasm, and high-level respect for education."

### Acting the part

These educational efforts, although they cross disciplinary and course boundaries, are linked by common goals. First, students should learn the process, as well as the content, of science. So even freshmen are acting like scientists, working together on open-ended problems, planning and doing experiments,

and reading scientific literature. Second, reformers link science to society, with classes often organized around real-world problems. Third, faculty members use strategies shown to promote active learning, such as grouping students into teams. Finally, these redesigned classrooms often employ a proliferating array of new technologies. All in all, the idea is to propel students into learning during class time, rather than in the library on the eve of the final exam.

For all their successes, reformers like Laws realize they have not yet carried the day. Most science departments offer a nontraditional course or two, usually for nonmajors, while the majority of science students scribble notes in lecture halls for 3 hours a week, then follow lab procedures many professors describe as cookbook. And although this generation of reformers documents its case with data on how well programs work, some faculty members and students still aren't convinced the new pedagogical techniques are worth the effort. "The total fraction of nontraditional instruction is still very small," says Bob Watson, director of the National Science Foundation's (NSF's) division of undergraduate education, which funds a diverse set of reform efforts. "We have a long way to go."

If "we" get there, it will largely be because of dissatisfaction with the results of traditional instruction. Many courses, especially at the introductory level, weren't doing justice either to the subject or the students, say educators like Laws. Lists of scientific facts failed to convey the nature of science. And many professors told Science they were dismayed by how little students actually understood, even after doing reasonably well in a course. Biochemist Harold White of the University of Delaware recalls a student who wrote a

paper on the life and work of Linus Pauling, but couldn't present the structure of vitamin C. Physicist Jack M. Wilson, who directs the Center for Innovation in Undergraduate Education at Rensselaer Polytechnic Institute in Troy, New York, puts it bluntly: "We pretended to teach them, and they pretended to learn."

It wasn't always thus: 50 or 100 years ago, points out NSF's Watson, science majors represented "a very small number of very focused students." Those students possessed excellent math skills and scientific backgrounds, learned rapidly, and planned to become scientists themselves. No more. Today, even the brightest stu-

### Innovative Teaching

**Employing new technologies**

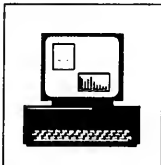
**Tackling real-world problems**

**Encouraging cooperative learning**

**Rewarding good teaching**

**Exploiting everyday materials**

**Teaching teachers to teach better**



## Curricula Reform Hits the Web

Physics professor Laurence Marshall sees it every day. Someone logs on to his computer from a terminal hundreds or thousands of miles away, rifles through a set of files, and copies several computer tutorials that Marshall has written for his astronomy students at Gettysburg College in Pennsylvania. "It happens all the time," says Marshall. And he isn't the least bit upset. "It's good to see others are finding [the tutorials] useful," he says.

Welcome to the world of on-line curriculum reform. In the first 9 months since his six computer tutorials went on the Internet, more than 1000 people around the world obtained free copies of everything from calculating the mass of Jupiter to the rate of expansion of the universe.

Educators hope that the on-line revolution will help them clear a hurdle that has tripped up previous reform efforts: The ideas are good, but they don't reach enough people to bring about lasting change. For years, reformers have used electronic mail and list servers—electronic mailing lists for particular discussion groups—to communicate with one another and swap stories about their successes and failures. Now they are taking the next step—designing computer-based course materials and instruction manuals and making them available to anybody with a computer, modem, and access to the Internet.

On-line reforms aren't limited to astronomers, of course. At California State University at Los Angeles, biologist Robert Desharnais and geologist Gary Novak have created a set of computerized biology and geology labs available over the Internet. At Georgia State University, computer scientist Scott Owen has put a set of 20 computer-graphics education programs on the wires. And engineering professors Robert Caverly of the University of Massachusetts at Dartmouth and John Bourne of Vanderbilt University in Nashville, Tennessee, have done the same with engineering labs.

Although only a few handfuls of on-line courses are currently available over the net, the number is expected to increase rapidly in the next few years. Indeed, educators and publishers have started to worry about a time when the Internet might become like public-access cable television, clogged with programs that are mediocre or, even worse, filled with inaccuracies. "Quality control is really important, especially in science," says James Lichtenberg, vice president of the Association of American Publishers. Because publishers have traditionally played that role, Lichtenberg predicts that they will move into on-line course distribution as the field grows.

Such on-line alliances with academics are already in the making. Calculus reformers, led by Deborah Hughes-Hallett at the University of Arizona, are offering free electronic support materials to accompany their new textbook published by John Wiley and Sons. Liesl Gibson of Springer-Verlag in New York says the company is considering distributing free software as a way to trim the size and cost of some of its text and lab books.

The National Science Foundation (NSF) is encouraging reformers to build ties with publishers in an attempt to maintain quality without sacrificing quantity. William Haver, a former NSF program director now at Virginia Commonwealth University, can imagine an arrangement through which courses and lab tutorials are distributed free over the networks at the same time publishers sell companion materials such as student's and teacher's manuals. In the meantime, Marshall intends to keep distributing his tutorials for free and let his users gauge the quality for themselves.

—R. F. S.

to see a lot of people making the same changes."

Although it is unlikely such grassroots movements will emerge simultaneously in all disciplines, there is good reason to expect modest improvements. In select disciplines, for example, broad-based faculty support for change already exists. A revised calculus curriculum that emphasizes concepts over equations is in the hands of roughly one quarter of the nation's 500,000 first-year calculus students. And "it's still picking up steam," says NSF's Spud Bradley, formerly associate executive director of the American Mathematical Society.

Chemistry reformers are also gearing up for a major overhaul. Last year, NSF received 112 requests for planning grants to overhaul chemistry curricula. And most of the 14 grants involved collaborations with as many as 10 colleges and universities apiece. To NSF chemistry program director Susan Hixon, the flood of proposals means just one thing: "The chemistry community is ready to change."

Of course, not all areas of the curricula are undergoing such sweeping change. In biology and physics, for example, reformers so far have focused on individual courses. In the past, such a piecemeal approach has tended to isolate reform-minded faculty even within their own departments. To discourage this scenario, funding sources like NSF and HHMI now actively solicit major research faculty and in many cases award curriculum reform grants to whole departments instead of individuals. At the University of Arizona, for example, researchers including Marty Hewlett, Richard Hallick, and Bill Grimes helped reform the school's introductory biology course to emphasize current research. And at Gettysburg College in Pennsylvania, biology professor Ralph Sorensen created a new biochemistry department featuring interdisciplinary courses such as molecular genetics. "These reforms can't just happen on the fringes," says Barkanic.

The word about reform is being spread by professional scientific societies and funding agencies. The American Chemical Society and the American Physical Society now regularly feature curriculum reform symposia at their annual meetings. At the recent American Physical Society meeting in Pittsburgh, for example, Dickinson's Laws was peppered with questions from dozens of her colleagues after a talk about her "Workshop Physics" course. And this year the American Society for Microbiology held a 1-day conference before its annual meeting to discuss curriculum development. NSF and HHMI are attempting to get the word out by bringing together those active in the reform movement. NSF also sponsors 15 regional summer workshops covering everything from new teaching techniques to the latest lab equipment.

With such outside support, many believe the current round of curriculum changes is here to stay. The most hopeful sign, believes HHMI's Barkanic, is a merging of innovative teaching and curricula. "You don't necessarily see all of the [solutions] happening in one department," he says, "but the awareness is growing that you have to move on a number of different problems at the same time."

However, awareness is only the first step. Unless faculty are given sufficient incentive to spend more time and effort on teaching, curriculum reform will remain the domain of the adventurous.

—Robert F. Service



Click and paste. Robert Desharnais' Karyotype helps beginning genetics students learn how to manipulate chromosomes.

## Rewards—at Last—for Top Teachers

Ohio State University plant biologist William A. Jensen was addressing his first class of the new term when a commotion broke out in the back of the lecture hall. To his amazement, Jensen spotted OSU's president, Gordon Gee, striding down the aisle ahead of various university and department officials, along with a camera crew. In his hand was the largest apple Jensen had ever seen—Gee's way of letting Jensen know he was one of eight faculty members chosen for excellence in teaching. "Let me tell you, I was pleased," says Jensen, the 2-year-old incident still fresh in his mind. It didn't hurt that the surprise "fruiting" was accompanied by a \$1500 check and a \$1200 raise.

Although most school administrators lack Gee's dramatic flair, the concept of rewarding good teaching is taking hold at universities across the United States. Science departments at small liberal arts colleges have long been known for their emphasis on classroom excellence, but university science departments have tended to hire and promote on the basis of research grants, publications, and scientific awards. Now, thanks in part to public displeasure with rising tuitions and falling test scores, that's starting to change—although whether the changes are dramatic enough remains open to question.

OSU's program, dating from the mid-1970s, was among the first. But many others have since joined the ranks of schools reordering their priorities. "We're paying a lot more attention to teaching when it comes to promotion and tenure decisions than we did a decade ago," says physicist June Matthews, undergraduate academic officer of the physics department at the Massachusetts Institute of Technology. The department also has started asking for three letters of recommendation addressing teaching ability, and student evaluations play a role in promotion decisions.

**Apple of his boss's eye.** William Jensen was honored by Ohio State president Gordon Gee—not for his grants, for teaching!

As with Ohio State, many schools are offering awards to drive home the notion that good teaching gets noticed. The University of California, Davis, pays \$25,000 each year to a single professor with an outstanding teaching record. The Virginia Polytechnic Institute and State University gave out 35 teaching awards last year, valued at up to \$20,000. Some went for individuals and others to departments to develop curricula. Individual winners are inducted into the school's "Academy of Teaching Excellence," and departments are marked by a special seal in college publications. For sheer generosity, though, it's hard to top the University of Florida. Last year, the school gave 165 faculty members raises of \$5000 each in base salary because of their performance in the classroom.

Although nobody objects to such teaching-based promotions and awards, some professors think their colleagues need more than cash to refocus their attention on the classroom. Subhash Minocha, a plant biologist who has been teaching at the University of New Hampshire for 20 years, says teaching needs a higher profile; he suggests "teaching chairs," dissemination of articles on teaching styles, and greater representation of teaching-oriented faculty on long-term planning committees. "This shouldn't only be about money or plaques," he says. "What we really need is continuous talk about the importance of good teaching."

The message also needs to be brought home to university administrators focused too narrowly on the short-term payoff of research excellence, says William Spicer, a professor of applied physics and electrical engineering at Stanford University. "An appreciation of teaching has to be built into the culture of the place," he says. "You have to get the feeling that the administration really cares." A few more presidents totting apples couldn't hurt.

—David Freedman

for various compounds; the results are turned over to county officials. As in research, students learn by making mistakes. "They'll get all excited over a peak at sample site number 5, want to see their duplicate measurement, and then find out they forgot the duplicate. Next time they remember," says Susan Kegeley, who designed the course with associate professor Angelica Stacy.

Teamwork is another tactic that nudges students into active roles and also prepares them for jobs in the real world. Educators call it cooperative learning, and former NSF program officer Stanley Pine got a vivid view of its power during a site visit last year to an NSF-funded experiment in an introductory chem lab at Clemson University in South Carolina. Pine attended a traditional lab, then crisscrossed the hall to a cooperative section of the same course and was shocked at the difference. In the traditional sections, he says, students "were so quiet, and the expressions on their faces were so dull; they just wanted to get done and get out of there." In the new class, "the kids were so excited about what they were doing; they were really communicating."

In the cooperative sections, student interaction and group output on both written and oral reports are so high that Chem 101 now meets the university definition of a "communications-intensive" course, says lab director Melanie Cooper. Educational studies have suggested that this approach also promotes gender equality, and Cooper found that to be true at Clemson. Only about 13% of the women dropped out of the cooperative sections, compared with 22% in the traditional sections. (For men, the rates were 8% and 9%, respectively.) Women in the new lab sections also performed better on the lecture exams.

Part of the impetus for cooperative learning comes from data showing that students who have just recently mastered a concept are sometimes better than a professor at explaining things to their peers (p. 890). Also, since a shrinking percentage of today's students will be remaining in academia and vying for faculty slots, there is less reason to rely on science classes to "weed out" the best and the brightest. Not only is experience in teamwork a valuable asset for grads seeking jobs in industry, it's also a crucial part of building a natural science community, says Jeanne Narum, director of Project Kaleidoscope, based at the Independent Colleges Office in Washington, D.C. The project identifies and disseminates successful programs and, like many of the new educational efforts, is funded by diverse sources, including NSF, the Department of Education, and several private foundations.

Narum's point is exemplified by the introductory physics course at the University of Delaware, where 180 students work in teams of four or five—and are graded as a group. "When you observe them, you find that they aren't talking about Saturday night's date," says professor David Onn. "They're actually talking about the problem, talking physics." Reports Tobias, who visited the class during a noisy group quiz. "The intensity of the conversations was absolutely thrilling."

The fourth major shift in pedagogical approach is technological, although not always in the gee-whiz vein. At Clemson, students used low-tech equipment, an economic necessity in some cases and part of a growing trend in chemistry (p. 889). But at other institutions the sky is the limit, with students using comput-

## Harvard Succeeds in the Teaching of Teachers

It's never easy watching oneself on videotape, but Harvard University physicist Melissa Franklin was especially nervous because she was about to witness what her students see. Worse, after 4 years in the classroom, she still rated her teaching abilities as merely "less than execrable"—so how would she look on tape?

The exercise was not as painful as Franklin imagined. Instead, she actually learned how to improve her teaching skills: Not only will she never again talk while erasing a blackboard (the students, she learned, need such moments to digest what they've been hearing), but she has cut down on those self-deprecating remarks offered to lighten the mood but which, instead, made her appear lacking in self-confidence. "Once you see it for yourself," she explains, "you don't need to be Piaget to figure out [its impact]."

The venue for Melissa Franklin's epiphany was a session at the Derek Bok Center for Teaching and Learning, founded in 1976 and one of the oldest of a handful of such university centers. The idea behind the program is that proven teaching ability is rarely a requirement for initial employment—indeed, it is too often lacking—despite the fact that graduate teaching assistants and junior faculty carry the bulk of the teaching load at most research universities. "The old approach was, 'Here's the textbook and good luck,'" says Daniel Goroff, a Bok Center associate director and a senior lecturer in Harvard's mathematics department. "Now we try to provide some real support."

Goroff has several weapons in his arsenal. The simplest are generic teaching tips like the one learned by Margot Seltzer, an assistant professor of computer science. Like most other teachers, Seltzer rarely endured more than a few seconds of silence after asking the class a question. Instead, she'd let the students off the hook by providing her own answer. Not long enough, Bok counselors told her. "Now I allow an uncomfortable, growing silence of 15 seconds or more, after which I tease and abuse the students into offering some kind of answer," she chuckles.

But the Bok Center also tackles more complex issues. Consider the experience of biologist Daniel Branton, who each year

teaches a large lecture class. Ten years ago, Branton brought in a dozen teaching assistants who lacked confidence and the skills to lead the students through the problem-solving techniques Branton wanted to instill. The solution was "microteaching"—that is, having the assistants conduct a 10-minute slice of a lecture in front of the others and a camera. Each performance was critiqued by Branton and the assistants, guided by Bok Center counselors.

Branton was initially skeptical—"I believed some people are unchangeably terrible explainers," he recalls—but the experience has changed his opinion. "Getting people to focus on presentation instead of subject matter is extremely helpful," he says. "It gave my assistants experience and confidence." Even as a 20-year chalkboard veteran, Branton learned a few things: His posture was sloppy, and he waved his hands too much. Now he dutifully herds each year's new batch of assistants to the center.

Branton's not the only newly convinced shepherd. The word has spread to the point where many departments actively promote the center's services among faculty. The economics department has even made it a requirement for continued employment, providing faculty with an appropriately economic incentive. And the center also tries to meet the special needs of every discipline. Graduate students scheduled to teach calculus observe other teachers and teach two practice classes in front of Bok Center counselors before striking out on their own. And physics grad students, often required to teach from day one, get a crash course.

For all Harvard's enthusiasm with the program, however, the Bok Center scrupulously avoids sharing its files with anyone but the teacher. That means no input on tenure or other academic decisions. "We'll tell a department if the teacher was here, but not how they did," says Goroff. "We're not the teaching police. We're here to help."

—David Freedman

*David Freedman is a science writer in Brookline, Massachusetts.*



Self-improvement. Melissa Franklin watches herself in action.

LARRY WOLFE/HARVARD UNIVERSITY

dents may be turned off by a focus on memorizing and abstract theories. And students now are much more diverse in their goals and backgrounds. At the Massachusetts Institute of Technology (MIT), for example, a changing student body prompted an experiment this fall in introductory physics, in which freshmen learn in small classes with less lecturing and more activities.

To accommodate student diversity, the new classrooms aim to nurture talents beyond memorization and good note-taking. So, be it at Dickinson or MIT—and whether the subject is physics, biology, or chemistry—more educators are adopting what is called discovery learning. Students make predictions, perform an investigation, and then analyze results. If this sounds a lot like research, there's a reason: The idea is to give students the flavor of the experimental process.

One example of this approach is the chemistry curriculum at the College of the Holy Cross in Worcester, Massachusetts, which is centered around lab investiga-

tions rather than the lecture. On the first day, freshman students explore whether pennies get heavier or lighter with age; that leads to experiments on the composition of pennies and the concept of density. Several semesters later, advanced students use the same discovery mode to explore the kinetics of reactions of cobalt compounds. "We wanted students to learn chemistry the way chemists actually do chemistry," says department chair Richard Herrick.

### Dipping into science

To engage those students who aren't inherently interested in abstract theories, many of these discovery courses are organized around real-world problems. For example, on the first day of introductory chem lab at the University of California, Berkeley, there's no one actually in the lab: Students have fanned out along the shores of a lake in a nearby park to see if the water is safe to drink. They plan their strategy, take samples, and test

ers to run experimental simulations, communicate by e-mail, organize their courses, graph data, write reports, and lots more (pp. 869 and 893).

One common approach literally gives students a new perspective: the use of 3D visualizations in biology and chemistry to help students see the structure of cells, proteins, and other molecules. "The hardest topics for me to get across are the things that I can see in my head that the students don't have a clue about," says chemist Nathan Lewis of the California Institute of Technology. "We want to put those things on screen for them." Such efforts run the gamut from low-budget programs that run on basic Macintosh computers to efforts like Lewis's, which involves a team of student animators led by a Hollywood special effects producer. The 10-minute videos show complex processes in 3D; at the end of the \$2-million project, you'll be able to watch atomic orbitals dance with *Jurassic Park*-style special effects.

#### Satisfying the customers

What do the students say about all this upheaval? According to course evaluations and interviews, most of them like it—although perhaps not at first. "The initial response is very negative," says Delaware's Onn. "Then, except for a core of about 20%, they all come to realize that they're learning at least as well as before and usually better."

Why would students balk at pedagogical reform that brings vivacity to the classroom? Students, educators explain, are likely to be wary of any change in the tacit contract between themselves and faculty. The new rules give them more responsibilities, and the demands of group projects make it more difficult to skip class.

Still, the majority of students respond to the new classrooms the way Hopkins did: They like it. In Berkeley's environmental chemistry laboratory, students "pour time into the lab—I think they shortchange the lecture," says chemist Stacy. Last spring, 83% of the students said they learned more than their classmates in traditional chem labs. At Rensselaer, 93% of students said they would highlight the problem-based calculus class as a positive reason for attending Rensselaer; only 63% of those in traditional classes made that statement, says Wilson. Students are also voting with their feet: Many faculty members using the new approaches report higher attendance rates, often above 90%.

Of course, the final decision on how to structure classes rests with faculty, not with students. And most science professors aren't ready to toss out their lecture notes yet. Discoveries and problem-solving are fine, they say, but not for every class. Biologists, facing an explosion of both knowledge and students, seem particularly concerned.

"You run into what I call 'the bit-rate problem,'" says professor Sarah Elgin of Washington University in St. Louis, who is redesigning the undergraduate biology curriculum with help from the Howard Hughes Medical Institute (HHMI) and other granting agencies. "In

the discovery method, the amount of information you can transfer per hour spent with the students is low. These students still have to pass the standardized admissions test for medical school. There is no more efficient, up-to-date means of information transfer than a good lecture." Biologist Yolanda Cruz of Oberlin College in Ohio agrees. "You can't get away from memorization in biology," she says. "They just have to know some vocabulary."

Still, most faculty members see some value in the new techniques. At Oberlin, chemistry department chair Robert Thompson is sold on cooperative and problem-based learning and is convinced his students are learning more. Biochemist White of Delaware thinks that lectures have their place, but that active learning is also essential. "What are we trying to teach students anyway?" he asks. "Knowing how to think and deal with problems is much more important than covering everything."

#### Implementing reform

Even for those faculty members who are ready, change takes time. "It really is easier just to put on a good show, to organize the material and do nice demonstrations," says Berkeley's Stacy. The pressure is acute at large research universities, where faculty members are typically working on their next grant proposal as well as operating a lab and teaching undergraduates. Stacy says she manages thanks to an extremely qualified teaching staff, including Kegeley. "We have no time for this kind of development," says Stacy. "We literally get zero credit for this. And you can't be topnotch in research if you spend half your time or more in courses."

A number of schools are seeking new ways to reward faculty for outstanding teaching, such as weighing student evaluations in promotion and tenure decisions, as done at MIT (p. 883). And NSF and HHMI officials say they hope the lure of megagrants—up to \$5 million in NSF's chemistry program—will help. Indeed, says Pinc, two thirds of the planning awards for those grants went to research universities—and one of the requirements is to show how teaching is rewarded on campus.

However, not all the disciplines are moving at the same rate. In undergraduate education, as in precollege teaching, the mathematicians have taken the early lead. "My observation was that the two areas where communities were most active and most ready to do things were mathematics and engineering," says NSF's Watson. So NSF launched specific curricular programs in those areas in the late 1980s. Last year the chemistry project was started in response to a growing clamor for change and because almost every science major takes chemistry.

And what of the biologists? "They're coming," says Narum firmly. Many biology departments are redoing their curricula (p. 856) and have embraced educational technologies (p. 888). But the biological community is less organized in its educational goals than is the mathematics or chemistry community, admits Narum, in



"We pretended to teach them, and they pretended to learn."

—Jack Wilson



Hands-on chemistry. Berkeley freshman takes water samples from the shore.



part because of the difficulty in achieving consensus across its many fields.

Meanwhile, although the reformers are generally headed in the same direction, they don't always agree on a particular strategy. For example, there's a controversy brewing over whether computers can replace lab courses. "On a computer you can do multiple runs, it always works, and no glassware is ever broken," says biologist Charles Ralph of Colorado State University, who taught freshman biology labs on computers for half a dozen years. On the other hand, chemist and NSF officer Pine thinks there's no substitute for getting your hands wet.

However that dispute is resolved, reform efforts appear to be picking up steam. At Rensselaer, where the reform spirit has penetrated almost every department, science faculty members generally find they like the change, says Wilson. "I'm learning a lot more," says biochemist White. "I'm not using the same overheads I did 4 years ago. The students are asking me new and unexpected questions. It's exciting, dynamic." If that feeling spreads, undergraduate science classes may never be the same.

—Elizabeth Culotta

## John Jungck: Godfather of Virtual Bio and Genetics Labs

Ethel Stanley, a biologist at Illinois's Millikin University, thinks something "neat" happens when she uses BioQUEST in her classroom. "Not only is the computer room busy," she marvels, "but the lounge is full of students who are actually talking about genetics." BioQUEST—a virtual lab—disproves a notion students acquire in school, Stanley says, that the lab is "a sterile place where nothing unexpected happens. Now they see it's a place where you make discoveries."

Stanley's fervent praise is not for a single commercial software package but rather a collection of 17 biology and genetics simulation programs that John Jungck, a molecular evolutionist at Beloit (Wisconsin) College, has godfathered into existence over the past 8 years. Most of the programs, such as the "Genetics Construction Kit" and "Sequence It," mimic the long-term strategies used in the lab. Others include a heart simulation program, an environmental decision-making model, and a program to teach statistics to biologists. The idea, according to Jungck, is to give undergraduate students the experience of research—from setting up experiments to presenting a paper—without having to build additional facilities meant for undergraduates. "A lot of science teaching is poor because it doesn't let students play at the game of science," says William Sofer, a molecular geneticist at Rutgers University who uses several BioQUEST programs with his students. "This gives students a feel for the fun of research."

Jungck designed the genetics kit, his first simulated computer lab, on an Apple II. A few years later, Jungck met Nils Peterson, a Washington State University hacker who shared Jungck's goal of giving students experience via computer simulations. With money from the Department of Education's Fund for Improvement of Post-Secondary Education (FIPSE), Peterson was then creating a computer model of the inner workings of the heart. In 1986 the two men joined forces—and simulations—and founded the BioQUEST consortium. The acronym stands for "Quality Undergraduate Educational Simulations and Tools in Biology." Jungck and Peterson next recruited 12 academicians—biologists, mathematicians, computer scientists, and educators—to develop more programs and landed a 3-year, \$360,000 grant from the Annenberg Fund of the Corporation for Public Broadcasting.

Last year, after several large-scale field tests, the first edition of the BioQUEST library (including 14 different lab courses) was released on CD-ROM. It has proved a tremendous hit with professors in undergraduate—and even graduate—biology and molecular biology courses across the country, from the Massachusetts Institute of Technology (MIT) to the University of Oregon. The level of sophistication ranges from graduate level to junior high school.

The key to the software is what Jungck calls the three Ps: problem posing, problem solving, and persuasion. In the genetics kit, for example, students are given a number of "field-collected" organisms with the genetic traits of *Drosophila*. Students then mate the fruit flies and from these crosses try to explain the inheritance patterns (and thus, the genes) that they see. Students must convince their teacher and classmates that their solution is a reasonable one.

"The question students ask me the most is, 'When am I done?'" says Jungck. "And, of course, nothing is ever really finished in science. But scientists—and the students—do reach a kind of closure when they are ready to communicate their results."

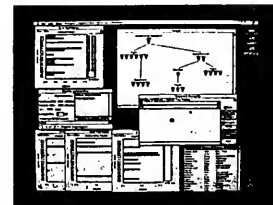
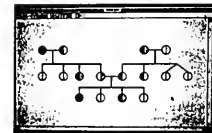
Yet for all the excitement the simulated lab can generate in a classroom, Jungck warns that it was not designed to replace the real lab. "I know that there are schools that want to use it that way, that see it as a means of cutting costs; but it will never replace a wet lab," he says. "Nor will it ever replace the teacher although it does change the way students and teachers interact."

Professors using BioQUEST agree on both points. "If you only used these programs, it'd be like looking at drawings of organisms and never looking under the microscope," says Vernon Ingram, a molecular biologist at MIT. "But what the programs are good at is teaching students how to design hypotheses and set up experiments."

The BioQUEST consortium now has more than 30 people developing programs for it and recently received a 2-year, \$400,000 NSF grant. "We expect to have 13 more programs ready by the end of this summer," says Jungck. "And while those writing the programs don't get financial remuneration, they do get a lot of satisfaction from serving science and the educational community."

—Virginia Morell

For more information on BioQUEST, contact: John R. Jungck, Biology Dept., Beloit College, Beloit, WI 53511, 608-362-1570



Genetic diversity. John Jungck's (top) growing BioQUEST computer library includes software to carry out clinical genetics case studies (middle) and to simulate a protein sequencing lab (bottom).

### ATTACHMENT III. DESCRIPTION OF SELECTED RESEARCH/EDUCATION ACTIVITY ICO CAMPUSES

#### AUGSBURG COLLEGE, MINNEAPOLIS, MN

Study of the Interaction of Solar Winds with Near-Space Environment, Professor Mark Engebretson

At Augsburg College, Physics Professor Mark Engebretson and three to four undergraduate students each year use data from NSF supported observatories in Arctic Canada and Antarctica to study the interaction of solar wind with the Earth's near-space environment. Two undergraduates helped Engebretson install instruments and data systems near the Arctic Circle during the summers of 1992 and 1993. Placing these instruments—which are very sensitive magnetometers—at the poles monitors changes the earth's magnetic field when a kind of northern lights, known as "dayside aurora," flex and reveal patterns in the flow of solar wind.

Dr. Engebretson's undergraduate students have participated in most aspects of his work, including: calibrating instruments; developing analysis software to run on computer workstations; and compiling data with simultaneous observations from research satellites. His students have had the honor of writing their own research articles on "space weather" for professional journals. Eleven students have been involved in Engebretson's NSF-sponsored research since it started in 1986; eight have gone on to graduate school, one to a 3-2 engineering program, and two to the Peace Corps.

#### COLBY COLLEGE, WATERVILLE, ME

Chemistry Program, Professor Bradford P. Mundy

Bradford P. Mundy currently has a group of 10 undergraduates working in all aspects of his research program. His work is supported by NSF, Research Corporation, and most recently by the Henry and Camille Dreyfus Foundation.

Since Colby College is only involved in undergraduate education, the marriage of research and teaching is required. In the past three years the chemistry faculty has made impressive use of the research enterprise to enhance the undergraduate teaching program. Examples of the research/teaching interface are numerous. The recent acquisition of Silicon Graphics workstations (through a NSF grant) used extensively for research by our students, has had dramatic impact on the whole instructional program. Every student going through General Chemistry at Colby has worked on these workstations. Other departments come and use these valuable computers: biochemistry has students building proteins and examining small molecule docking; physical chemistry and advanced organic students make extensive use of these computers. A recent analysis shows that the computational facility services 11 semester courses! Thanks to this technology and the NSF which made the purchase possible, our seniors, upon graduation, can comfortably carry on advanced computational chemistry. Without doubt, the workstations have fundamentally changed how we do business.

Colby chemistry, with only 1,700 students, is fortunate to have in its Chemistry Department a 400 MHz nuclear magnetic resonance spectrometer.

#### COLLEGE OF ST. CATHERINE, ST. PAUL, MN

Research in How Genes of Halophilic Archaeobacteria Stabilize the Structure of Biological Macromolecules and Studying Evolutionary Relationships of the Halophilic Archaeobacteria With Other Cell Types. Dr. Kay Tweenen

Dr. Tweenen has developed her research program to characterize halophiles, bacteria with unusual properties which might be useful for industrial processes. Her research provides valuable opportunities for undergraduate women to explore their scientific, creative, and intellectual potentials. It provides them with research experiences which are becoming more and more essential during undergraduate years if these women are to be accepted into professional and graduate programs. Over the past six years, Dr. Tweenen has worked with several undergraduates (about 20 different students) in her lab. Students have generated results which have been presented at several scientific conferences and which are currently being prepared for publication. Dr. Tweenen has also closely integrated some aspects of her halophilic research with laboratory learning experiences in courses she teaches such as microbiology, cell biology, and molecular biology.

DESCRIPTION OF SELECTED  
RESEARCH/EDUCATION ACTIVITY  
—JCO CAMPUSES  
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This undergraduate research has been supported through a grant from The Research Corporation, college faculty development funds, and three grants from the National Science Foundation Instrumentation and Laboratory Improvement Program.

DICKINSON COLLEGE, CARLISLE, PA  
Study of the Cytoskeleton's Role in Cellular Motility, Professor Jim Henson

A myriad of fundamental processes from fertilization to cell division and differentiation depend on a cell's ability to move around and to rearrange its internal components. All this moving and changing happens thanks to something called the cell's cytoskeleton—an array of numerous filamentous and motor proteins which structure and animate the cell. Dr. Henson is learning more about the nature and function of a subset of these cytoskeletal proteins and uses cells derived from marine animals as model experimental systems. He uses sea urchin blood cells and embryos, clusters of skate liver cells, and cultured shark cells in his research. At the very least, the results of these studies will help further general cellular knowledge, but they may as well as help us to know the role of cytoskeleton in cellular diseases. All of these projects have included the extensive involvement of undergraduate students as research colleagues in labs and even as co-authors of scientific meeting presentations and published abstracts and manuscripts.

FRANKLIN AND MARSHALL COLLEGE, LANCASTER, PA  
X-Ray Fluorescence Vacuum Spectrometer, Dean Stanley Mertzman

NSF instrumentation funded Dean Mertzman's proposal for a new x-ray fluorescence vacuum spectrometer (\$140,000 with \$35,000 matching by the college) two years ago. Franklin and Marshall is the only strictly undergraduate institution in the nation with this new generation of Philips 2400 machines; this has moved the college onto the blade of the cutting edge of research into the elemental chemical composition of solid materials.

Usually, "solid materials" studies means looking at rocks and minerals. Since he is a geologist, Mr. Mertzman uses the Philips 2400 in the petrology course he teaches to about 20 juniors and seniors a term. Students do individual hands-on research projects over the course of two months while learning the necessary analytical techniques so they can do their own chemical analyses. This is exciting work.

Thanks to the spectrometer, the college has started cooperating with a local company, Armstrong World Industries, a ceiling and floor tile manufacturer. Ceiling and floor tile are obviously solid materials, so the work with Armstrong is easy and beneficial. The company's research and analytical staffs work with Franklin and Marshall as well, including providing instrumentation to the school.

It often happens that Franklin and Marshall students come through the lab and ask why bunches of floor and ceiling tile are there, then they figure out that the techniques of they are learning at Franklin and Marshall are transferable—it's not just rocks and minerals.

FURMAN UNIVERSITY, FURMAN, SC  
Undergraduate student researchers program in chemistry, Professor Lon Knight

Dr. Lon Knight has six undergraduate students doing work in chemistry for him each year. This research is managed by NSF's chemistry division, and funded through the Experimental and Physical Chemistry and Research Experience for Undergraduates programs, both of NSF. Fortunately, NSF grants serve as seed money—giving Dr. Knight the opportunity to seek matching funds from local corporations.

A sample research project description is the experimental electron spin resonance measurements of matrix isolated cations and anions will provide valuable electronic structure information which will be shared with several theoretical research groups for collaborative analysis and interpretations. This important interaction can help guide the various experimental strategies and assist the development and testing of the latest approaches in computational chemistry. Scientific information obtained from these studies could be important in several

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different areas, including: deposition processes of semi-conductor materials involved in the fabrication of several neutral radicals; the identification of new interstellar species from nuclear hyperfine patterns; the characterization of small metallic cluster radicals and reactive intermediates involved in catalytic processes and potential upper atmospheric radicals.

GRINNELL COLLEGE, GRINNELL, IA

Instrument to Study the Dynamics of Single Pinned Vortices of Magnetic Flux in a Superconductor, Professor Charles Cunningham

Dr. Charles Cunningham, Assistant Professor of Physics, is building a novel instrument to study the dynamics of single pinned vortices of magnetic flux in a superconductor. The motion of such vortices has a deleterious effect on nearly all applications of superconductors, from high-field magnets to superconducting electronics to SQUID magnetometers. This will be the first instrument in the U.S. able to study the pinning of single vortices with both high spatial and temporal resolution. Thus far, three undergraduates have participated in this project, which is supported by an award from Research Corporation.

HOPE COLLEGE, HOLLAND, MI

Study of Relationship Between Parasite Infestation and Cancer Incidence, Professor James M. Gentile

Dr. Gentile researches the relationship between parasite infestation and cancer incidence in mammalian hosts. His results give a better understanding of the special problem of parasite-infestation of humans in regions of the world where higher than normal cancer incidence occurs.

Using genetic endpoints that include the microorganisms *Salmonella typhimurium*, and immunodiagnostic methods for carcinogen-DNA adduct formation, Dr. Gentile's group has been able to suggest the mechanisms for the genetic damage in parasite-infested mammals. These mechanisms include: i) the inducibility of highly specific genes in mammalian liver that result in a highly localized increase in some specific cytochrome P450-carcinogen metabolizing enzymes; ii) an increase in oxygen radical production and/or nitric oxide in the inflammatory areas immediately adjacent to parasite-induced injury sites, iii) the production of exogenous carcinogen-DNA adducts in mammalian cells immediately adjacent to parasite-induced injury sites. These data indicate that the presence of parasites and transient enzyme kinetics coupled with diffusion problems of highly reactive molecules may lead to genetic damage resulting in a higher incidence of neoplasia.

In the last five years a total of 24 undergraduate students have participated in this research. Of these students, 10 have either obtained a Ph.D. or are working toward one, nine others are in professional school (medical, dental, etc.). Of the five remaining former students, one is a teacher and the others are researchers in academia or industry.

LAKE FOREST COLLEGE, LAKE FOREST, IL

Investigations Combining Marine and Molecular Biology to Learn How Marine Animals Cope with Salt Stress, Professor David Towle

During the last ten years, David Towle's NSF-supported research at Lake Forest College, University of Richmond, and Mount Desert Island Biological Laboratory has directly involved more than 20 undergraduates in investigations combining marine and molecular biology. Their mission has been to learn how marine animals cope with salt stress. Towle's students, from Illinois, Virginia, Maine and seven additional states, have discovered that marine animals use some of the same mechanisms of salt regulation found in human kidneys. By understanding how marine creatures successfully respond to salt stress, Towle hopes to develop new ideas for controlling hypertension in the human population. Ninety percent of Towle's research students have gone on to graduate or medical school. In addition, over 750 students in Towle's courses in cell and molecular biology have benefited, often directly, from the NSF-sponsored research.

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LAWRENCE UNIVERSITY, APPLETON, WI  
Molecular Biology Program, Professor Beth DeStasio

Professor Beth DeStasio has initiated a program in molecular biology at Lawrence University that expands the scope of a biology major by involving students in advanced research. She has located previously unknown suppressor genes critical to muscle development in nematodes, mutations of which can restore mobility to paralyzed specimens. This research had direct application to biomedical science and is supported by grants from Howard Hughes Medical Institute and the Muscular Dystrophy Association, as well as NSF. Her students study protein interactions necessary to muscle development, have reversed the paralyzing effects of mutant genes in laboratories, and explored recombinant DNA applications.

MACALESTER COLLEGE, ST. PAUL, MN  
Applied Studies in Biology, Professor Daniel J. Hornbach

Dr. Hornbach is a researcher currently studying the impact of the zebra mussel on indigenous mussels in the St. Croix River. His project has two major parts: 1) field studies to determine the influence that zebra mussel invasion may have on the population density and community structure of unionid mussels, and 2) laboratory studies to examine the physiological effects of zebra mussel colonization on the physiology of unionid mussels. Hornbach's research in this area is supported by more than \$635,000 in grants from the Environmental Protection Agency and the Department of Interior's Fish and Wildlife Service. His research on the river's biodiversity actively involves six student research assistants each year, and it has resulted in numerous faculty/student publications in professional journals and presentations at professional conferences. This research would be impossible to conduct without the facilities of the college's Aquatic Ecology Laboratory, renovated in 1992 with support from NSF. Equipped with living streams and growth chambers, the laboratory supports year-round research and is able to accommodate the entire research team.

MANCHESTER COLLEGE, NORTH MANCHESTER, IN  
Research in Marine Ecology and Biology, Professor Alan Holyoak

Manchester College offers a research-intensive experience for undergraduate students in the field of marine ecology. This off-campus program runs during the college's three-week January term, at a marine research station. Pairs of students conduct their own research in marine ecology, and then make written and oral presentations of their work. Financial support for the program comes directly from student participants. In January 1995 fourteen undergraduates with the program went to the Friday Harbor Laboratories, at the University of Washington. It is likely that two of the eight student projects done in during this project will be published in professional journals.

Manchester College also offers an undergraduate student research experience in biology. In the spring of the junior year, students develop a research proposal under the guidance of a faculty mentor. In the fall of the senior year, the student presents a written report to the Biology Department, and makes an oral presentation in the Science Division's weekly seminar. Financial support for the program will come from the Biology Department and student participants. We anticipate 6-12 students in the program each year.

OHIO WESLEYAN UNIVERSITY, DELAWARE, OH  
Isolation of Feather-Degrading Strains of Bacterium

The isolation of feather-degrading strains of bacterium found on bird plumage by Ohio Wesleyan faculty and students holds promising agricultural, environmental and industrial applications. This collaborative research by Zoology, Botany/Microbiology, Chemistry and Physics faculty focuses on an enzyme produced by strains of *B. licheniformis* that could lead to a marktable use of the tons of poultry feathers discarded each year. National

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Science Foundation, Pew Charitable Trusts and Howard Hughes Medical Institute grants support student research and/or equipment acquisition for this study. Over the last two years, 21 undergraduate students have actively participated in this exciting research.

POMONA COLLEGE, CLAREMONT, CA

Social and Hormonal Influences on the Development of Sex-specific Song in a Tropical Wren, Professor Rachel N. Levin

Professor Levin is studying social and hormonal influences on the development of sex-specific song in a tropical wren. Each year, he collects nestlings from the Panamanian rainforest with three to four undergraduate students. Birds are hand-raised at Pomona College in individual acoustic chambers in which they hear tapes of both male and female songs. Eight students hand-raise and tape-tutor birds, then analyze the songs these birds sing. Three students perform hormone assays on plasma from these birds. This work is funded by Professor Levin's NSF NNI and RUI awards, and by an NSF REU grant on which she is co-PI.

REED COLLEGE, PORTLAND, OR

Replication of Viruses with RNA Genetic Material that Replicate in Yeast, Professor Peter Russell

Peter Russell, a nationally recognized geneticist, has worked in his laboratory with a total of 24 students since 1991, when, with NSF RUI support, he began studying the replication of viruses with RNA genetic material that replicate in yeast. The project's goal is to define viral sequences that are necessary for viral replication, and then to identify yeast genes the products of which influence viral replication. Dr. Russell is typical of Reed teacher/researchers who serve as mentors to students and provide opportunities to do cutting-edge research at the undergraduate level.

UNIVERSITY OF REDLANDS, REDLANDS, CA

Low Energy Proton Cross Section Studies, Professor Richard Carlson

Richard Carlson is the University of Redlands most active researcher. He has three research institutions (two in the U.S. and one in Sweden) which pursue him and his research hoping to have him continue his work at their facilities instead of at Redlands. His only funding comes from a research corporation grant. Last summer four undergraduate research students worked with him; they were each paid a stipend from the University's Science Center budget. Because the student interest in undergraduate summer research is booming at Redlands (for example, in three summers we have gone from three to 14 students in science and math research assistance positions), Dr. Carlson is now writing a proposal for NSF's Research in Undergraduate Institutions program (RUI). 90% of the funds for research assistance programs like Dr. Carlson's undergraduates come from the University budget, which now puts us at our limit. The University is struggling to find external support so we can meet the student interest in these involve more students, and continue high-quality research of international renown.

FCCSET Committee on  
Education and Human Resources  
FY 1992 Budget  
(\$'s in Millions)

*See the Attachments*

EDUCATION LEVEL/ MAJOR PROGRAM AREAS	AGENCY													
	FY 92 BUDGET	NSF	EO	DOE	DOC	NASA	DOJ	HHS	EPA	USDA				
REQUEST														
UNDERGRADUATE: FORMAL & INFORMAL.....	477.38	132.32	16.10	30.18	176.08	1.90	25.03	8.83	70.14	4.30	12.50			
Program Evaluation/Assessment.....	0.14	0.00	0.00	0.10	0.30	0.00	0.00	0.00	0.04	0.00	0.00			
UNDERGRADUATE: FORMAL TOTAL.....	368.64	131.33	16.10	0.00	107.30	1.90	8.85	3.59	66.68	0.39	12.50			
TWO-YEAR: FORMAL TOTAL.....	14.26	6.38	0.00	0.00	0.00	0.09	0.50	0.10	7.19	0.00	0.00			
Faculty Preparation/Enhancement.....	2.79	2.25	0.00	0.00	0.00	0.00	0.50	0.02	0.02	0.00	0.00			
Curriculum Development, Total.....	2.55	2.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Curriculum/Materials.....	0.25	0.25	---	---	---	---	---	---	---	---	---			
Laboratory Equipment.....	2.30	2.30	---	---	---	---	---	---	---	---	---			
Comprehensive (Org. Reform).....	1.58	1.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Student Incentives.....	6.72	0.00	0.00	0.00	0.00	0.09	0.00	0.08	6.55	0.00	0.00			
Direct Student Support.....	6.72	---	---	---	---	0.09	---	0.08	6.55	---	---			
Bridging Programs.....	0.00	---	---	---	---	---	---	---	---	---	---			
Other.....	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00			
FOUR-YEAR: FORMAL TOTAL.....	334.39	124.95	16.10	0.00	107.30	1.81	8.35	3.49	59.50	0.39	12.50			
Faculty Preparation/Enhancement.....	25.46	25.30	0.00	0.00	0.00	0.00	0.00	0.06	---	0.10	0.00			
Curriculum Development, Total.....	69.78	61.11	6.10	0.00	0.00	0.20	1.66	0.50	0.16	0.05	0.00			
Curriculum/Materials.....	47.02	38.37	6.10	---	---	0.20	1.66	0.50	0.14	0.05	---			
Laboratory Equipment.....	22.76	22.74	---	---	---	---	---	---	0.02	---	---			
Comprehensive (Org. Reform).....	39.19	12.38	0.00	0.00	6.80	0.00	1.68	0.53	5.30	0.00	12.50			
Student Incentives.....	197.15	24.81	10.00	0.00	100.50	1.61	4.85	1.39	53.75	0.24	0.00			
Direct Student Support.....	197.15	24.81	10.00	---	100.50	1.61	4.85	1.39	53.75	0.24	---			
Bridging Programs.....	0.00	---	---	---	---	---	---	---	---	---	---			
Other.....	2.81	1.35	0.00	0.00	0.00	0.00	0.16	1.01	0.29	0.00	0.00			

Tom Cech remembers his NSF Graduate Fellowship as the vehicle that gave him the spirit of independence that continues to influence his life. Not content to limit himself to the challenge of basic biochemical research, Cech regularly dedicates time to a variety of community activities. He volunteers to teach freshman chemistry classes to more than 500 students and gives "Mr. Wizard" lectures to younger audiences—all in all, not behavior typically associated with a Nobel-prize-winning chemist.

Today Cech heads a research group at the University of Colorado at Boulder that he characterizes as "eclectic." Its interests range from synthetic, organic, and physical chemistry, to biochemistry and structural biology, to retrovirology and medical applications. Increasingly, it is the serendipitous research from such interdisciplinary groups that fuels significant new discoveries.

Although he started out in physical chemistry, Cech found real satisfaction with biochemistry and the study of the DNA molecule, thus launching his productive career. This love is also the basis of his great interest in teaching freshmen, an experience that allows him to incorporate the key ideas of biochemistry into the chemistry curriculum.

Cech's association with NSF began during high school with his participation in a Summer Science Training project in radiation physics at the University of Iowa. Later, in his senior year at Grinnell College, he won an NSF Graduate Fellowship for Ph.D. work at the University of California, Berkeley. The next fall, when he and his wife entered graduate school at Berkeley, he was free to focus his research interests without regard to whether his mentor could support him.

That is precisely how the Graduate Fellowship program works. It seeks to identify the best young scientific and engineering talent in the United States and gives them the chance to pursue their dreams in whatever research group is most appropriate. In recent years, Cech notes, the "shoe has been on the other foot." The occasional participation of NSF Fellows in his current research group greatly increases Cech's flexibility in working with graduate students.

The NSF Graduate Fellowship program has provided the opportunity for young Americans to pursue mathematics, science, and engineering graduate studies. Many have gone on to make significant contributions to the scientific community, and 12, including Cech, have been honored with the Nobel prize. Today, almost 2,800 American graduate students in nearly 180 colleges and universities around the world are continuing this tradition and creating a talent base that will be prepared to meet the unknown scientific and technological challenges of the next century.



## TURNING POINTS



## Brock Spencer



In 1991, Brock Spencer changed the way he teaches. Spencer's involvement in the NSF-funded Project Kaleidoscope (PKAL) National Colloquium led to the revision of Beloit College's introductory chemistry course, which was experiencing an almost 20-percent dropout rate. Encouraged by the educational models presented at that conference, Spencer and his colleagues, Laura Parmenier and George Lisensky, took steps to revitalize and restructure the course. The "conversion" of Brock Spencer had begun.

Spencer's new chemistry course trades lectures and examinations for more time in the laboratory, and it employs pedagogies Spencer observed at the PKAL colloquium. The new chemistry course emphasizes taking a problem, refining the approach, evaluating the results, and finding answers to student-posed questions—questions, according to Spencer, that may be more directly relevant to a student's individual experience than those a professor would ask. As a result, students now use their textbooks as a source to solve problems, rather than as a course blueprint, and lectures have become discussions about issues students find interesting or difficult.

with each other, and to teach themselves."

Thanks in part to PKAL, the dropout rate in the course is half of what it used to be. Now, students come away from the course with a better understanding of how science progresses and contributes to society. The only problem has been supplying enough sections to meet the growing demand; almost half of all Beloit College students have taken the course by the time they graduate.

The influence of PKAL has had a ripple effect. Beloit faculty in other scientific disciplines are impressed with the success of the changes Spencer instituted from his PKAL experience, and in some cases they have incorporated more laboratory work into their own courses. Spencer's course now serves as a basis for developing and testing materials for an NSF-funded project to introduce solid-state concepts and examples into general chemistry courses.

"PKAL's National Colloquium has brought undergraduate science to the forefront of the academic agenda," says Spencer. "Now we have a coherent picture of the challenges facing us."

In 1993, PKAL introduced Spencer's new chemistry course in the report *Programs That Work*, which was designed to provide models for other institutions attempting to strengthen and reform their courses. Since then, Spencer has presented workshops throughout the country on reforming chemistry courses, including several at PKAL conferences and one at a PKAL regional conference held at Beloit in August 1993. Spencer and PKAL have shown faculty from hundreds of colleges and universities why a hands-on approach to science should not be saved for advanced courses only.

Spencer's conversion continues. He now heads the Chemlinks Coalition formed with the support and influence of PKAL. The coalition, a group of 15 liberal arts institutions, has received a planning grant from NSF to reform the first two years of undergraduate chemistry instruction. The coalition will rely on PKAL resources and will use Spencer's new course as a foundation for its reforms as it strives to develop effective ways to attract all students, especially those with diverse learning styles, into science.

*"It is more important in today's technological climate for students to learn to ask important questions, to work with each other, and to teach themselves."*

# NATIONAL SCIENCE FOUNDATION

Mr. SCHIFF. Thank you very much, Dr. Ferguson.

I am going to recognize for five minutes Mr. Ehlers, and then I am going to invite Mr. Ehlers to take the Chair for a few minutes in my place, and I will be right back.

Mr. EHLERS. [presiding] I want to thank the panel for their testimony. Frankly, I have very little in the way of questions because I agree with virtually everything you said.

I appreciate the comments made about the various aspects of the program.

So I am going to recognize Ms. Lofgren next for five minutes.

Ms. LOFGREN. I don't think I will need five minutes. I just had two lines of questioning.

One was for Dr. Colwell. I was interested in your comments about the level of support for research. I am wondering what recommendations you would have for enhancing of funding for research.

What should we do, in your view?

Dr. COLWELL. I think at the minimum we should at least maintain the research at the previous level that was recommended, and that the research be sufficient to allow our young investigators to be able to have an opportunity to enter the field.

Because we are in a way sort of using our seed corn. We are not allowing our opportunities sufficient funding for new starts for our young investigators.

Ms. LOFGREN. So what additional funds? Do you have a dollar figure in mind that you think we should add?

Dr. COLWELL. I would recommend that the asking budget should be funded.

Ms. LOFGREN. Okay.

The second question I have, or line of questioning has to do with science education before undergraduate.

I was looking at your attachments, Dr. Ferguson, in the science innovations on campus.

I don't receive this periodical, but I was wishing that I also had a copy of the "Coping with Unprepared Undergraduate" article.

I am very concerned that even if we have excellent graduate and undergraduate programs in large sections of the country, we are not adequately preparing children K to 12 to enter into the scientific field.

I know, for example, in Silicon Valley last year a majority of the engineers hired in Silicon Valley were foreign graduates.

I certainly have nothing against foreign scientists, but I think our future requires us to invest in children so that we have fully allowed for their development and their creativity to lead us into the 21st Century.

I am interested—I understand, and I am new to the Congress and this Committee, that there is apparently a need to evaluate what we have done. But I am interested in the thoughts that any of the panelists might have on what the next initiative might be in K-12, and in science and math education.

Do we do fractals for 4th graders on the Internet?

What do you think?

What advice would you have for us in that arena?

Dr. FERGUSON. I certainly agree that there is a problem with people coming to college unprepared in some areas, and that needs to be addressed. But I think the most important reason right now for focusing on undergraduate education is not in the that sense of it is K through 12 has had its turn, it is what we are seeing when we have 3rd grade teachers, as Mr. Sawyer suggested, telling his granddaughter that she can't go on in math and science, it is because that third grade teacher is afraid of math and science.

I think that at the undergraduate level when we can really help the students going through not just to take some education courses, but to actually learn the subject matter so that they are no longer afraid that that is going to have the appropriate effect.

Ms. LOFGREN. If I might say, I highly support what you are suggesting.

I am just also aware that, for example, in the San Francisco Unified School District in my District, you know, 85 percent of the teachers have been there for more than 12 years and, because of funding in California in particular, that new wave of teachers is going to take a while to trickle through the system.

Meanwhile, millions of children are facing science teachers who are afraid of science, and what do we do about that generation?

Do you have any thoughts, any of you? Dr. Colwell is nodding her head.

Dr. COLWELL. I think that it is critical that we engender in our youngsters to maintain the scientific inquiry that they have naturally in them.

Studies have shown that somewhere in the 3rd or 4th grades, particularly for girls, there is almost a stultifying or a suppression of what is a natural scientific curiosity.

All of us do experiments everyday when we test, for example, the temperature of the coffee that we drink. We are obviously doing an experiment.

Is it safe enough to drink?

I think the curiosity of the scientific curiosity needs to be maintained under encouragement. The problem I think we have is that our best and brightest do not end up going on into science and engineering, and they should.

I think that is really the problem. The symptom is the number of foreign scientists.

The problem is that we do not have an educational process that encourages these youngsters to go on to their natural abilities.

We have not mentioned it much this morning, but we should. We have a serious problem with our minority, native born population.

It is clearly important for us to strengthen the capacity for science and engineering in bringing these individuals into the scientific and engineering community.

Ms. LOFGREN. I guess my time is up.

Mr. SCHIFF. [presiding] The ladies time has expired.

Mr. LUTHER?

Mr. LUTHER. Thank you, Mr. Chairman.

I appreciate it.

I don't have questions to take up the full five minutes myself, but I am a new member, and so this is a learning process for me and I appreciate your presentations.

I guess the area that I would ask you to focus on just a bit, if you could, and if I missed it I apologize, but it is the whole area of how we go about doing the best we possibly can in a climate of fiscal restraint?

We are obviously facing fiscal considerations here. I think people would tell you that regardless of which side of the aisle they are on.

Although I am new here, I have spent many years in state government. One thing that always concerns me when we are making budget cuts is that there is always a tendency sometimes for the cuts to be made, or the reductions to be made in those areas where there is the least resistance.

The easiest cuts, which may not sometimes be the best places, are the most strategic places to do it.

What can you share with us in terms of in a time when we are looking at greater fiscal restraint, what can we do to ensure that we are maximizing the utilization of the dollars that we do have available, and doing this and trying to achieve this in the best possible way from the standpoint of the country?

Dr. COLWELL. I will make a first cut at an answer.

I think scientists do not like to prioritize. We resist it because we like to think that everything is important. I guess in the broad, global view of things, they are.

However, we have begun to undertake prioritization, and I think that we need to have a partnership between those who are providing the funding and those who are at the receiving end—namely, the scientists.

For example, the American Society for Microbiology has begun an analysis of those areas of the life sciences that specifically in microbiology are most likely to provide some of the most exciting new findings.

These then will be listed in a report that will be shared with the Federal agencies as a means of providing advice as to the best and wisest investment.

It is not an easy thing to do, but I think it is something that we have to consider doing very seriously.

I think also that what is happening is that in education, and perhaps my colleague, Dr. Ferguson, would like to speak to it, but we are beginning to find ways to be more cost-effective and to utilize the new capacities of the computer in providing modules for teaching and enhancing self-instruction in teaching.

In other words, we are undergoing I believe in higher education, especially, a kind of a transmogrification in the ways we are doing things. This is to the good.

I think we will continue to be able to partnership with the funding agencies in providing advice and counsel and feedback, if you will.

Dr. FERGUSON. I think what I would like to stress as an answer to your question would be the reason to support the National Science Foundation's budget is that, in times of fiscal restraint, the last thing we all need to do is be reinventing the wheel.

I think the NSF has done a very good job, at least in my experience in the last few years, of trying to bring various constituencies together.

For example, on the undergraduate level which clearly would be the one I was most involved in, to have voices at the table from research institutions, from community colleges, from engineering schools, as well as liberal arts colleges, the NSF has been able to leverage individual pieces of information and expertise and create a stronger whole.

I think they can do that. I know they have done that in other areas, too. I think that that is one of the things that the NSF does well, is it leverages the Federal dollars that it gets.

Mr. LUTHER. Mr. Chairman, I may have a follow-up, but Ms. Jackson Lee has indicated she has a time constraint, so could I yield to her?

Mr. SCHIFF. All right. The gentleman's time will be reserved.

Ms. Jackson Lee is recognized for five minutes.

Mr. LUTHER. Thank you.

Ms. JACKSON LEE. Thank you very much, Mr. Chairman, and thank you very much to the gentleman from Minnesota. I appreciate it.

I will be very quick.

Dr. Pings, I just wanted to ask you in relation to the Land-Grant Colleges and the other institutions, how effective has NSF been with, for example, a Prairie View A&M, or other traditionally black institutions, in assisting them or in responding to their request for inquiries for a funding for some of their scientific work?

Dr. PINGS. I am not an expert on those patterns of funding, but I believe this has been one of the areas that the Foundation has paid particular attention to.

The EPSCOR Program has provided a mechanism for those regions geographically that have not had patterns of historic aggressive funding from the Foundation to aggregate their potential to put in research grants and be funded.

The whole intent was to get programs up to the level where they could be fully and openly competitive.

So I think this is under attention fully at the Foundation, and I would defer to the Assistant Directors there to provide you additional information on that.

Ms. JACKSON LEE. Thank you very much.

Thank you, Mr. Chairman.

Thank you, Mr. Luther.

Mr. SCHIFF. Mr. Luther, you have about a minute-and-a-half left. You are recognized again.

Mr. LUTHER. Thank you, Mr. Chairman.

I happen to agree with the comments you made about how in a time of fiscal restraint the last thing we should do is cut back our science, if you will, in terms of—in fact, when I see the extent to which we tend to focus on the kinds of issues we are focusing on here in this Congress, it just tells me that we are spending too little time thinking about the future, the next Century, our competitiveness in the next Century, and those kinds of issues.

So I am glad to hear you say that.

As a follow-up question, I would just ask you, do you think a process needs to be formalized so that—do you think a process needs to be formalized that assures us that we are getting the ab-

solute best dollar, best bang for our buck, if you will, in this time of fiscal restraint that we are about to enter?

Do we need a more formalized process than we have had in the past?

Dr. PINGS. Let me take a one first pass at this.

You have a formalized process. It is called the National Science Foundation, and it is called the National Institutes of Health, and so forth.

But specifically, I think you should be reassured that the National Science Foundation with its long pattern of seeking and aggressively fostering competition and proposals for their work, reassures all of us, both in the scientific and engineering community and those that look at us from without, that whatever the dollar amount is, it is going for the best possible science that we can imagine at a given time.

That is so in the time of increasing budgets. It would be so in the time of flat budgets. It would be so in the time I hope we do not have to face of constrained budgets.

The process is working.

Furthermore, the diversity of programs within the Science Foundation itself should also reassure us that ideas have ways of percolating up through different channels within the programs of the Foundation to be tested.

If they are meritorious, to be funded. To go forward if the scientific results seem to provide the underpinnings for that forward decision.

I think we do not need new programs. We certainly need to affirm our commitment to what I believe is in place in a very healthy National Science Foundation.

Mr. SCHIFF. The gentleman's time has expired

Let me ask, as I did with the last panel. Does any Member of the Subcommittee have a further question that they might like to briefly ask this panel at this time?

Ms. Lofgren?

Ms. LOFGREN. Not an additional question, but Dr. Colwell was just about to respond to the last question. I would be interested in her response.

Mr. SCHIFF. I am sorry.

I guess—

Ms. LOFGREN. No, I do not think you noticed it.

Mr. SCHIFF. —I did not mean to cut off a witness.

Ms. LOFGREN. I know that.

Mr. SCHIFF. Dr. Colwell, please feel free to respond to the last question.

Excuse me for cutting you off.

Dr. COLWELL. I wanted to affirm the excellent response of Dr. Pings. Indeed the National Science Foundation record is excellent.

I think that amongst the scientific community it is clearly recognized as being the most effective in its disbursement of funding.

In the peer review process it may have its slight flaws, but it is certainly the best that we have been able to devise, and it certainly ought to be continued.

Mr. SCHIFF. Dr. Ferguson, did you wish—

Dr. FERGUSON. I absolutely agree with both of the previous speakers.

Mr. SCHIFF. Thank you for that reminder.

Let me ask again.

Any further brief questions of the Subcommittee?

[No response.]

Mr. SCHIFF. I don't see any requests.

Before I terminate the hearing, though, I did not take my five minutes, and I am going to take a small portion of it just to comment on the budget references which have come up frequently, and for good reason, in your testimony and the testimony of the previous panel.

I want to say that it is my personal view as a Member of Congress that it is imperative that we in some manner balance the budget.

I think it is unconscionable. I think it is immoral what we are doing to future generations.

Even in terms of the present time, we spend over \$200 billion a year off the top of our budget—this is right now—on interest on the national debt.

Imagine how much we could supply to the National Science Foundation and all the other activities we have talked about if that \$200 billion did not just essentially go out the window each year?

However, I also believe that in the process we have to do our best to fight for our priorities. We do not know who is going to win that battle.

We do not know who is going to lose it. There will be winners and losers.

But I want to say that I asked to serve on the Science Committee six years ago before there was any possible thinking that I or a member of my Party might in the near future actually hold chairmanships here, because I believed and believe still today that science is the solution to so many problems that we have, from a better law enforcement, through better technology, to better productivity in our work force and world competitiveness.

To me, scientific endeavor applies universally throughout what we do as a society. To the best of my ability, I will fight for science as a priority.

With that, I want to thank—

[Mr. Bloch arrives.]

Mr. SCHIFF. Timing is everything, Mr. Bloch.

[Laughter.]

Mr. SCHIFF. Mr. Bloch, I am going to invite you to give a brief statement, if you desire, but I need to terminate this hearing in the very near future.

I want to say, we do understand that your plane was late.

We do welcome you here as a former head of the National Science Foundation yourself, most certainly, and invite—I will take a few minutes, with everyone's indulgence, to invite you, if you want to make any comments, and then I think in fairness to ask the Subcommittee Members if they would like to ask you directly any questions.

**STATEMENT OF ERICH BLOCH, DISTINGUISHED FELLOW,  
COUNCIL ON COMPETITIVENESS, WASHINGTON, D.C.  
[FORMER DIRECTOR, NATIONAL SCIENCE FOUNDATION]**

Mr. BLOCH. Thank you very much, Mr. Chairman, for your courtesy.

I am sorry that I am late, but it was beyond my control.

Mr. SCHIFF. Technology is not yet perfect.

Mr. BLOCH. No, it is not; especially not with the airlines.

Let me just take 60 seconds to summarize what I would have wanted to say, and then leave it up to your questions.

I think the World and the Nation and what NSF does today is different from what was the case 40 years ago.

Let's recognize that and make sure that the resources that NSF has are adequately to accomplish its very manifold kind of tasks. And over time, its mission has increased and has now decreased.

I also hope that we do not narrowly define the programs that it executes, but realize that research is driven by the interaction of problems, people, and institutions, from many walks of life, and not by very narrow disciplinary lines, nor by very arbitrary and artificial definitions of what kind of research is being conducted.

I also hope that NSF can play its role of working with industry and academia without distorting their unique goals, as well as that of NSF.

I also hope that a too-narrow interpretation of the government role, like science-only, for instance, or divorcing government research from that of the private sector's research, is counter-productive, and I hope that we realize this.

I support the request that NSF has made. It is an increase, and I understand that, and I think it is up to this committee, obviously, to judge if that is within your power to grant with all the problems that exist.

Let me just make one point—one small but important point—on some of the details of its budget.

I was kind of taken aback when I saw a decrease, a percentage-wise decrease, in the education and human resources project.

I think that is a bad signal that we give to the public at large, and to the academic community, and I would hope that we can balance within the same budget line research and related activities which are important, no doubt about it, with that of education and human resources, and equalize those out.

Because I think the problems we have in the country are in the education area. Not only K through 12, but also undergraduate.

With that, thank you very much.

[The prepared statement of Mr. Bloch follows.]



## Council on Competitiveness

TESTIMONY

E R I C H   B L O C H

Distinguished Fellow, Council on Competitiveness

before the

SUBCOMMITTEE ON BASIC RESEARCH  
OF THE HOUSE COMMITTEE ON SCIENCE

March 2, 1995

TESTIMONY OF ERICH BLOCH  
DISTINGUISHED FELLOW, COUNCIL ON COMPETITIVENESS

BEFORE THE  
SUBCOMMITTEE ON BASIC RESEARCH  
OF THE HOUSE SUBCOMMITTEE ON SCIENCE

March 2, 1995  
-----

Mr. Chairman and Members of this Committee:

Thank you very much for this opportunity to speak to you today as part of the process to re-authorize the National Science Foundation.

My name is Erich Bloch, and I am the Distinguished Fellow at the Council on Competitiveness. The Council is a nonprofit, non-partisan organization of chief executives from business, higher education and organized labor who have come together to improve the ability of American companies and workers to compete in world markets, while building a rising standard of living at home.

Before joining the Council, I was for many years at IBM in many positions, ranging from research to development and manufacturing to corporate management. In 1984 I was appointed Director of the National Science Foundation (NSF) by President

Reagan. While at NSF and in my present position, my concern has been, and remains, the linkage between science and technology and the country's economic competitiveness and the strengthening of the nation's investment in R&D in general, but civilian R&D in particular.

#### **Council's Position on R&D**

The Council over the years has focused on science and technology policy. In fact, as the 104th Congress convened, it issued a "Statement on R&D Policy and Competitiveness" because it felt that this topic should be high on the agenda of the new Congress. (See attached.)

There are four principles we advocate.

1) Science and technology are key to the nation's economic growth and its competitiveness. Much of our productivity growth during the post-World War II period, has been due to our mastery of science and technology.

2) The government has a central role to play in ensuring that we maintain the leadership in science and technology. R&D budget priorities should focus on promoting the R&D base and on R&D programs that are relevant to competitiveness.

3) Industry, academia and the government must work together in an active partnership. This cooperation is increasing and new partnerships are being formed in response to challenges in the global economy.

4) Regulatory relief and tax incentives must be part of R&D policy. R&D must be viewed as a system that is influenced by market incentives.

I am dwelling on these principles because they form a necessary framework for today's hearing on NSF. We also need to keep today's environment in perspective and compare it to the environment that existed at the time NSF was created:

- the Cold War was in high gear, today it is economic competitiveness that is a major driving force;
- the defense requirements were paramount in determining priorities in the country's R&D system. Today the needs of the global market, determine, at least in part, our strategic research;
- mega-programs were de rigueur. Today critical technologies pre-occupy us;
- natural resources drove industry and the well being of

countries. Today it is knowledge, information and education and a country's standing in these areas, that determine a nation's standard of living.

**Purpose and Mission of NSF.**

I want to differentiate between NSF's purpose and mission. The purpose of NSF, namely "to promote the progress of science; to advance national health, prosperity and welfare; to secure national defense..." has been invariant over time and, moreover, has been broad enough for NSF to be able to respond to the nation's needs over the last four decades.

Congress created an independent agency -- one that would not be bogged down with its own intramural research and its own laboratories -- that is guided by the combination of a presidentially appointed director and a National Science Board that reflects a broad cross section of the research and education community. Acting together, the Board and the Director set the policies and programs of the Foundation.

Congress, which chartered and periodically amended the enabling legislation of NSF, has created and maintained a unique institution. In so doing, it has recognized the broad aspects of research and the many facets required for NSF to function. As a consequence, NSF has the authority to concern itself with:

- engineering as well as the sciences;
- research of all kinds, fundamental as well as applied;
- education, at all levels, as well as research;
- partnerships, not just narrow constituencies;
- groups, centers as well as individual investigators;
- the collection, analysis and dissemination of information for policy formulation;
- efforts to facilitate the participation of all geographic regions and citizens in science and engineering.

Both the purpose and mission of NSF fulfill the Council's principles on science and technology I discussed before. In particular, NSF has exemplified the central role Government needs to play in ensuring our leadership in science and technology and has fostered the partnership that is evolving between industry, academia and government.

**NSF Programmatic Goals.**

NSF's programmatic goals, as established through its recently published strategic plan, include:

- excellence in science, math and technology education at all levels;
- leadership of the U.S. in mathematics, science and engineering;
- creation and dissemination of knowledge in the service to society.

I believe these are all in line with both NSF's purpose and mission.

NSF's focus on supporting research and education in interdisciplinary -- or what is also called strategic -- areas has had material effects on industry and academia alike, worldwide and here in the United States. While one can always argue whether the current NSF strategic initiatives are the priority areas NSF should concentrate on, there can be no disagreement that priorities need to be established -- in conjunction with the interested research community from government, academia and industry -- instead of a disjointed approach that merely reacts passively to what ever is

requested by the research community.

Let me single out the High Performance Computing and Communications program as an example.

While today a government wide program, it was NSF and what was then DARPA that spearheaded this economically important research effort. This program laid the foundation for nothing less than a paradigm shift from serial stream vector machines to massively parallel computing, which is causing a restructuring of computer architecture and of the industry as well. The basic research in the universities provided the foundation for industry to move forward on a high risk path and cut many months or maybe even years of development time from their schedule.

The emergence and high visibility of the National Information Infrastructure is largely due to the investment this program made in universities and the partnership it created with industry. Again, much of the industry restructuring is due to the insights and the stimulus this program provided.

Not so incidentally, in both cases, parallel computing and information networks, the country and our industry is far ahead of its foreign competitors. I doubt that the case would be as clear cut if the government had not participated and provided the needed academic funding, that industry could leverage.



One more point needs to be made: NSF has taken a broad view of its role in the research enterprise, and this serves the Nation well. NSF's programs address research and education in science and engineering in broad and comprehensive ways. They support both disciplinary research, primarily through single investigators grants, as well as interdisciplinary research through centers. That is the right approach.

There are many voices today that are calling for Congress to constrain agencies to narrow areas for fear of straying into "industrial policy." Fear not. The reality is, that the interaction of a concern with applications, fundamental insights and unconstrained experimentation is the cauldron out of which new ideas and new inventions emerge. Insights and relationships are the focus, not narrow definitions of what is basic, applied or pre-competitive research and what is not.

#### **NSF Budget.**

The budgetary reality you and your colleagues in Congress are facing is stark. No program and no agency should be immune from scrutiny -- and this includes the Foundation. Assessing an agency's budget is difficult, and I am not about to critique the budget in detail -- but I will highlight some issues.

First, we need to differentiate between the funding of activities and the cost of administration. NSF has kept that cost below a 5 percent level, which is an accomplishment and perhaps can be used as a model for assessing other comparable activities.

Second, expenses can be avoided by not doing what is not necessary. Many rules and regulations, that were instituted at one time because of a particular problem, are not really needed to run an efficient operation. Congress, the Administration and the Foundation should critically assess all the rules under which it and its "customers" operate, and reduce them, without giving up a necessary control of the operation.

Third, NSF is asking for an increase of about 3 percent. This Committee and the rest of the Congress will have to weigh this expenditure against all others to determine the appropriate level of support. Keep in mind, NSF's unique role is that it "enables" our research enterprise to perform, to develop and to apply new knowledge, and to educate and train our scientific and technological workforce. It does no research itself, and I would argue, therefore, that the NSF model is an extremely efficient and cost-effective way for the Federal government to support the research enterprise it is so dependent upon. This should be reason enough for Congress to fully support the Foundation's budget proposals.

I would also argue that in trying to set Federal R&D priorities, we should not increase the overall Federal R&D budget. Instead, we should consider revising the mix of federal intramural versus extramural supported research. According to the President's own FY 1996 budget, about 30 percent, or \$25 billion, goes to support intramural research throughout the various agencies. That is too high by a factor of two and invests in research that, by any account, is less efficient and less flexible than research in academia or the private sector.

Fourth and last, I have one criticism of the proposed allocation in the 1996 budget. Whatever the total NSF budget will be, why are we reducing the Education and Human Resources budget by 1 percent, instead of increasing it by a proportion equal to that of the Research and Related budget line? Both pre-college and undergraduate education are our Achilles heels. The coupling of research and education in our research universities needs stressing. While the proposed budget of \$600 million for Education and Human Resources is not inconsequential, a reduction in expenditures and an increase in research could send the wrong signal to faculty, students and their parents.

#### **Concluding Points**

Congress, in first chartering NSF and then updating and focusing on its mission, has created an agency that has stood the

test of time.

What the world, the nation and NSF do today is different from what was the case 40 years ago. Let's recognize that and make sure:

- that the resources NSF has are adequate to accomplish its manifold tasks;
- that we not narrowly define its programs, but realize that research is driven by the interaction of problems, people and institutions from many walks of life, not by narrow disciplinary lines, nor by arbitrary and artificial definitions of what kind of research is being conducted;
- that NSF can play its role of working with industry and academia without distorting their unique roles, as well as its own;
- that too narrowly interpreting the government role, like science only, or divorcing government research from that of the private sector's research and needs, is counterproductive.

Finally, since the Congress may yet consider legislation to reorganize the Executive Branch with respect to R&D, let me offer

an organizational suggestion for Congress itself. No one committee is responsible and oversees the totality of the Federal R&D budget. This Committee lacks authority over the National Institutes of Health (NIH) biomedical research activities and the Defense Department's research and development activities. And in the appropriations process, nine different subcommittees -- all facing a wide variety of competing claims and not enough resources -- have jurisdiction over parts of the Federal R&D establishment. It is time, in its effort to make itself more efficient, that Congress address this shortcoming.

Mr. Chairman, thank you for this opportunity to appear before your Committee.

## STATEMENT ON R&D POLICY AND COMPETITIVENESS

As the 104th Congress begins its historic work, efforts to promote research and development (R&D) should be high on the agenda.

In fashioning R&D policy, the Congress should keep in mind three fundamental principles.

**First,** science and technology are key to the nation's economic growth. Economists attribute the unprecedented productivity growth of the United States during the post-World War II period to its strength in research and development -- a conclusion borne out by the continuing global competitiveness of such American industries as telecommunications, computers, financial services, pharmaceuticals, chemicals, textiles, aerospace and agriculture. No program to improve the standard of living and quality of life of the American people can succeed without ensuring the nation's continued leadership in science and technology.

**Second,** the government has a central role to play in ensuring that the United States maintains that leadership. This principle has long been a subject of bipartisan agreement. The federal government has contributed to the nation's success in science and technology in numerous ways since World War II. It has financed about half the nation's research, supporting work in universities, corporations and government laboratories. It has promoted science education, university facilities and advanced telecommunications, putting in place the

groundwork for a thriving R&D enterprise. And it has spearheaded work to accomplish national missions, such as exploring space, improving health and maintaining national security, that, in turn, have sparked industrial innovation and increased productivity.

**Third,** government, industry and academia must work together in an active partnership for science and technology to move forward. Merely continuing 50-year-old R&D policies will not be enough to succeed in an era of global competition. In recent years, Republican and Democratic administrations, working with the Congress, have begun to frame a joint R&D policy for the post-Cold War world based on this notion of cooperation. We need to build on that foundation.

To promote cooperation, government must help create a tax and regulatory environment in which R&D can flourish. The new Congress should ensure that tax laws help increase the availability of long-term, patient capital; that regulations stimulate rather than stifle the R&D efforts of industry and universities; and that intellectual property receives adequate protection.

Government must also see that its own R&D dollars are spent in a way that enhances the long-term competitiveness of the United States. At a time when both federal and corporate budgets are under stress, this is more important than ever. The new Congress should support programs that provide incentives for private partners to pool their R&D capital and expertise to invest in long-term and riskier projects.

The private sector must continue to do its part as well. Industry has begun to focus its R&D on improving manufacturing and market performance. Universities are revamping their curricula and research programs to improve the nation's productivity. These efforts must be sustained and strengthened.

The new willingness of government, industry and academia to work together has already born fruit. The 1994 Critical Technologies Update recently published by the Council on Competitiveness showed that the United States has begun to regain its edge in a wide range of technologies. But a Council survey also found that most American business, labor and academic leaders believe that the nation's greatest competitiveness challenges still lie ahead.

The need to respond to this continuing challenge -- some might say "threat" -- must guide Congressional action in the first 100 days, and beyond. No new agenda, no new program, no new policy will succeed over the long term if it undercuts the ability of the United States to innovate and compete. We urge the Congress to move swiftly to eliminate regulations that unnecessarily encumber R&D and investment in new technology; to enact tax reforms and incentives that stimulate private R&D; and to continue to support federal R&D investment that enhances the nation's competitiveness and encourages cooperation among the government, industry and academia. We stand ready to work with the Congress to develop a comprehensive R&D strategy that includes all three of these elements.



## Signatories to Statement on R&amp;D Policy and Competitiveness

Ernest Mario  
Co-Chairman and Chief Executive Officer  
**Alza Corporation**

John R. Stafford  
Chairman, President and  
Chief Executive Officer  
**American Home Products Corporation**

Richard C. Notebaert  
Chairman and Chief Executive Officer  
**Ameritech Corporation**

Joel Marvil  
Chairman and Chief Executive Officer  
**Ames Rubber Corporation**

Ray Stata  
Chairman of the Board and Chief  
Executive Officer  
**Analog Devices, Inc.**

Jack Sheinkman  
President  
**Amalgamated Clothing and  
Textile Workers Union, AFL-CIO, CLC**

William Archey  
President  
**American Electronics Association**

James C. Morgan  
Chairman and Chief Executive Officer  
**Applied Materials, Inc.**

William V. Muse  
President  
**Auburn University**

Richard M. Rosenberg  
Chairman and Chief Executive Officer  
**BankAmerica Corporation**

John Clendenin  
Chairman of the Board  
**BellSouth Corporation**

Charles A. Heimbold, Jr.  
President and Chief Executive Officer  
**Bristol-Myers Squibb Company**

Thomas E. Everhart  
President  
**California Institute of Technology**

Robert Mehrabian  
President  
**Carnegie Mellon University**

Daniel J. Meyer  
Chairman and Chief Executive Officer  
**Cincinnati Milacron Inc.**

Robert J. Paluck  
Chairman and Chief Executive Officer  
**Convex Computer Corporation**

Frank Rhodes  
President  
**Cornell University**

James R. Houghton  
Chairman and Chief Executive Officer  
**Corning Incorporated**

John F. Carlson  
Chairman and Former  
Chief Executive Officer  
**Cray Research, Inc.**

Henry B. Schacht  
Chairman  
**Cummins Engine Company, Inc.**

Thomas J. Murrin  
Dean  
**Duquesne University**

George M. C. Fisher  
Chairman, CEO and President  
**Eastman Kodak Company**

Sidney A. Taurel  
Executive Vice President and  
President, Pharmaceutical Division  
**Eli Lilly and Company**

G. Wayne Clough  
President  
**Georgia Institute of Technology**

Robert A. Ingram  
President and Chief Executive Officer  
**Glaxo Inc.**

Alan Magazine  
President  
**Health Industry Manufacturers Association**

Brian D. McLaughlin  
President and Chief Executive Officer  
**Hurco Companies, Inc.**

Louis V. Gerstner, Jr.  
Chairman and Chief Executive Officer  
**IBM Corporation**

Gordon E. Moore  
Chairman of the Board  
**Intel Corporation**

Peter Likins  
President  
**Lehigh University**

Charles M. Vest  
President  
**Massachusetts Institute of Technology**

Raymond V. Gilmartin  
Chairman, President and  
Chief Executive Officer  
**Merck & Co., Inc.**

Horst K.D. Wallrabe  
President, Pharmaceutical Division  
**Miles Inc.**

T.J. Malone  
President and Chief Operating Officer  
**Milliken & Company**

Lucio A. Noto  
Chairman of the Board and  
Chief Executive Officer  
**Mobil Corporation**

Gary L. Tcocker  
Chief Executive Officer  
**Motorola Inc.**

Joseph R. Hardiman  
President  
**NASDAQ Stock Market**

Jerry Jasnowski  
President  
**National Association of Manufacturers**

John Decaire  
President  
**National Center for  
Manufacturing Sciences**

Monte L. Phillips, Ph.D., P.E.  
President  
**National Society of Professional Engineers**

Saul K. Fenster  
President  
**New Jersey Institute of Technology**

William Ferguson  
Chairman and Chief Executive Officer  
**NYNEX**

Charles M. Pigott  
Chairman and Chief Executive Officer  
**PACCAR Inc**

Philip J. Quigley  
Chairman and Chief Executive Officer  
**Pacific Telesis Group**

William Steere  
Chairman and CEO  
**Pfizer Inc**

Gerald Mossinghoff  
President  
**Pharmaceutical Research and  
Manufacturers Association**

G. Gilbert Cloyd  
Vice President, Pharmaceuticals  
**The Procter & Gamble Company**

Steven C. Beering  
President  
**Purdue University**

R. Byron Pipes  
President  
**Rensselaer Polytechnic Institute**

Sanford R. Robertson  
Chairman  
**Robertson, Stephens & Company**

Albert J. Simone  
President  
**Rochester Institute of Technology**

Donald R. Beall  
Chairman and Chief Executive Officer  
**Rockwell International**

Daniel B. Hartley  
President  
**Seattle Professional Engineering  
Employees Association**

William H. Reed  
President  
**Semiconductor Equipment and  
Materials International**

Andrew Procassini  
President  
**Semiconductor Industry Association**

Papken S. Der Torossian  
Chairman and Chief Executive Officer  
**Silicon Valley Group, Inc.**

John Young  
Chairman  
**Smart Valley, Inc. and  
Former Chief Executive Officer  
Hewlett-Packard Company**

Walter Y. Elisha  
Chairman of the Board and CEO  
**Springs Industries, Inc.**

William R. Greiner  
President  
**State University of New York at Buffalo**

Jerry Junkins  
President and Chief Executive Officer  
**Texas Instruments Incorporated**

Deane D. Cruze  
Senior Vice President  
**The Boeing Company**

Frank Popoff  
President and Chief Executive Officer  
**The Dow Chemical Company**

W. R. Timken, Jr.  
Chairman  
**The Timken Company**

Edwin Artzt  
President and Chief Executive Officer  
**The Procter & Gamble Company**

W. Ann Reynolds  
Chancellor  
**The City University of New York**

Stephen Joel Trachtenberg  
President  
**The George Washington University**

Peter Peterson  
Chairman  
**The Blackstone Group**

John D. Ong  
Chairman of the Board  
**The BFGoodrich Company**

Charles E. Young  
Chancellor  
**University of California, Los Angeles**

Nils Hasselmo  
President  
**University of Minnesota**

Steven B. Sample  
President  
**University of Southern California**

David Ward  
Chancellor  
**University of Wisconsin-Madison**

Joe B. Wyatt  
Chancellor  
**Vanderbilt University**

Paul Allaire  
Chairman and Chief Executive Officer  
**Xerox Corporation**

Bernard V. Vonderschmitt  
President  
**Xilinx Inc.**

*As of February 1, 1995*

Mr. SCHIFF. Thank you, Mr. Bloch.

Let me state that your written statement will be made a permanent part of this record.

I am going to very briefly ask the Members of the Subcommittee if they desire to ask you any questions at this time.

Mr. Ehlers?

Mr. EHLERS. Thank you, Mr. Chairman.

Mr. Bloch, during the rest of the hearing there was a great deal of discussion about strategic versus curiosity-based research it was called in some cases, others called it investigator-initiated research, and I expressed my opinion on that, that we should not have that distinction, and in fact we should not talk about strategic research.

But I am not necessarily asking you to agree with me, but I was wondering if that was an issue when you were still the Director of the Foundation? Or did that come after your tenure?

Then I would also ask for any other comments you might have to offer on that.

Mr. BLOCH. Well that certainly was an issue. No doubt about it. It came up especially when we established engineering research scientists and the science and technology centers, and later on, by the way.

Let me just say one thing. We have labeled "research" by all kinds of adjectives, some of them that you cited. Another one is "precompetitive research."

I think we are cutting it much too fine, and that was my point I tried to make before.

I think there is a differentiation and there needs to be a differentiation between research in general—fundamental research, basic research, precompetitive research—and what is required for product development.

There should be a firewall between the two.

But to erect walls between fundamental research, and basic research, and applied research, and so forth, I think is not doing us any justice, number one, and secondly it inhibits relationships that should exist.

That is especially true in a very fast-moving kind of a field where these differences blur. Ask the people what they are doing and sometimes they don't know if it is basic research or not, and they could not care less.

Mr. EHLERS. Thank you very much, Mr. Chairman.

Mr. SCHIFF. Ms. Lofgren?

Ms. LOFGREN. Just the question I asked the other panelists. I had noted on page 11 in your written testimony your comment about the Education and Human Resources budget.

I am also—and I know everyone on this committee, as well as all the panelists are—concerned about the need to grow scientists here in our own country, and the fact that we are not doing as good a job in that regard as we know we need to do.

I am wondering, both in terms of undergraduate education as well as K-12, what thoughts you have, in addition to fully funding efforts, we should make to get ahead of this situation we are currently in.

Mr. BLOCH. I would hope that we make a much closer linkage between research and undergraduate education. That was really

my point before, that we give the right signals to our researchers and universities, and to the faculty and universities, especially undergraduate education in the sciences and in engineering.

If you watch the "60 Minutes" program last Sunday, you saw essentially the gap that exists. Now much of that is perception and not reality, but it really doesn't matter.

Ms. LOFGREN. Very quickly on K through 12 education, I have, and I know that we have talked about the new efforts to improve training of teachers in the area of science and math, which I endorse. But most of the children of America will be taught by teachers who have not gone through those programs as undergraduates. What thoughts do you have that we could do in the near term to bring high-level scientific education to youngsters.

I kiddingly, but not really, said, you know, should we have fractals for 4th graders on the Internet. I mean my experience just as a parent and someone who has spent a lot of time in elementary schools, is there are 10-year-olds who are not inhibited from understand the chaos theory in the way an adult is.

What are your thoughts that we could do in the near-term in that arena?

Mr. BLOCH. Well, I think you hit on the one thing I think we should use some new tools more effectively and efficiently. I do not know if I would want to teach chaos theory to a kindergarten pupil, but the general idea is the right idea.

You know, that we bring programs, that we bring individuals via the Internet to K through 12 schools and classes, so that people see that there is a real living behind these things and it is not just fiction of somebody's imagination.

Ms. LOFGREN. Thank you.

Mr. SCHIFF. I am almost hesitant to declare the Subcommittee adjourned this time, but I do not see any other requests to speak. So let me thank this second panel of witnesses. I thanked the first panel of witnesses very, very much. I declare the Subcommittee hearing adjourned.

[Whereupon, at 12:35 p.m., the hearing was adjourned.]

## APPENDIX

NATIONAL SCIENCE FOUNDATION  
4201 WILSON BOULEVARD  
ARLINGTON, VIRGINIA 22230



OFFICE OF THE  
DIRECTOR

April 19, 1995

Honorable Steve Schiff  
Chairman  
Subcommittee on Basic Research  
Committee on Science  
House of Representatives  
Washington, D.C. 20515

Dear Mr. Chairman:

Thank you very much for the opportunity to appear before your subcommittee to discuss the Foundation's proposals for FY 1996. Enclosed with this letter are our responses to the questions for the record that you posed to us.

I hope you find this information useful and responsive. I look forward to continuing to work with you and the subcommittee as the NSF authorization process moves forward.

Sincerely,

Neal Lane  
Director

Enclosure: Questions and Answers for the Record

cc: Honorable Pete Geren

## QUESTIONS FROM THE HOUSE SUBCOMMITTEE ON BASIC RESEARCH

### University Research and University-Industry Collaborations

**QUESTION:** Currently, there has been a good deal of discussion about some of the more technologically-oriented federal research and development programs. In this climate, could you explain the Foundation's view of the roles of university-based research and university-industry collaborations in increasing our Nation's competitiveness and overall economic health?

**ANSWER:** Fundamental scientific and engineering research performed at the Nation's universities and colleges is essential for training innovative scientists and engineers, for fostering technology improvements, and for achieving the revolutionary advances that create new industries. Such research has led to a host of commercially important technologies such as lasers, fiber optics, micro-electrical mechanical devices (MEMS), CAT scanners, biotechnology, composite materials, superconducting materials, and microelectronics. In the future, path-breaking fundamental research will yield capabilities unimaginable only a few years ago and will no doubt form the basis for entire new industries.

Recently, NSF has been emphasizing the support of research in strategic areas of national priority. Research in these areas ranges from civil infrastructure systems, manufacturing and biotechnology, to the environment. This research is fundamental in nature and permits individual researchers to pursue their own creative ideas but within a larger context of knowledge in service to society.

University-industry collaborations are important because they help make the essential knowledge transfer between the different sectors and better prepare students for careers in industry and government. Such cooperation brings many disciplines and backgrounds together to solve complex problems and can increase the potential for early application of the knowledge generated.

### Definitions of Research

**QUESTION:** There continues to be discussion regarding the relative importance of various "types" of research, discussion that is accompanied by a fair amount of confusion concerning the definitions of various terms. Could you please provide the Foundation's viewpoint of the terms "strategic," "curiosity-driven," interdisciplinary," etc., as used with respect to the conduct of research? How do these concepts fit together.

**ANSWER:** There are many different ways of classifying research:

- By kind of research objective (basic, applied, development; standard OMB classification);
- By field of science and engineering (disciplines; interdisciplinary activities);
- By mode of support for the research (single investigator, group, center, user facility);



- By where (or by whom) the research is done (industry, federal labs, colleges and universities);
- By how and why the activity is initiated (planned research program that directs the investigator's action; investigator-initiated with various motivations).

Classifications usually assume sharp, well-defined categories. Most of these classifications don't fit that assumption.

Curiosity motivates all good research, whatever the classification. But there are other motivating influences as well, including the promise that the knowledge resulting from the research will benefit society.

The traditional basic/applied/development classification is misleading. It assumes that there is a regular progression in research from basic to development. However, we know that there is feedback in this progression, and that the same types of projects may bounce back and forth between categories or even fit into more than one at the same time.

NSF-supported research focuses on the discovery of new fundamental knowledge, and hence, falls primarily in the basic category. A small amount is classified as applied -- usually portions of projects that are inseparable from the basic research components.

NSF-supported research activities cover all fields of science and engineering except biomedical research, where the National Institutes of Health have the major responsibility. Increasingly, we find exciting science at the interfaces of traditional disciplines.

NSF uses all modes of support for research, with emphasis on single investigators and small groups. Most of the activities we support are carried out at colleges and universities.

The modifier "strategic" has been used to describe research areas or programs that can be related to such broad national priorities as biotechnology, civil infrastructure systems, manufacturing, environment and global change, etc. Research in "strategic" areas can be basic (emphasized by NSF) or applied; performed by universities, federal laboratories, or industry; carried out by single investigators or groups; in centers or in user facilities. "Strategic" is not truly a classification of research, but rather a way of illustrating how even basic research can benefit people's lives.

Confusion in the use of various terms to describe research arises from:

- Assuming the terms are mutually exclusive.
- Equating the categories of one classification with those of another. For example, people frequently equate curiosity-driven with basic, and strategic with applied, forcing an identification that is not there. Other examples might be equating strategic and interdisciplinary, or interdisciplinary with funding for centers or large groups.
- Confusing agency suggestions for areas of funding emphasis with direction to the researchers on what projects they should undertake.

### Social and Behavior Research

**QUESTION:** There are many people who believe that social and behavioral research are vitally important to understanding the present and preparing for the future. What is the Foundation's view of these disciplines and how has the development of the social, behavioral and economic sciences directorate progressed to date? What does the future hold in store for this important area?

**ANSWER:** The National Science Foundation strongly supports research in the social and behavioral sciences. Support for this set of disciplines stood at \$65 million in FY 1992; the request for FY 1996 is nearly \$92 million, an increase of almost 42 percent.

The Directorate for the Social, Behavioral and Economic Sciences has in the past two years:

- brought to fruition plans for a national Center on the Human Dimensions of Global Change, an activity first recommended by a Committee of the National Academy of Sciences in 1992;
- expedited the plans of anthropologists, population geneticists and population biologists to determine the variability that exists in the human genome;
- developed a research program designed to build a science base for understanding quality within organizations;
- encouraged enhanced coordination, within NSF and across Federal agencies, of research under the Human Capital Initiative, covering integrated, multidisciplinary empirical research to produce comprehensive science-based understanding of the factors affecting the development of human capital in the U.S.; and
- made it possible for the highly innovative Science and Technology Center for Cognitive Science at the University of Pennsylvania to accelerate and disseminate its research on human cognition.

The Foundation has encouraged efforts to inform the general public of the contributions social and behavioral sciences have made to our understanding of our past and present, and the vital role these sciences will play in understanding matters that loom on the horizon. The Foundation takes pride in the fact that awards through the social and behavioral sciences:

- provided the basis for the recent FCC auction of broadcast spectrum licenses; economic research on game theory produced new models used in the innovative auction design that yielded over \$100 billion in proceeds.
- documented that contacts through friends and families are important in effective job searches, and often lead to better, higher-paid and longer lasting jobs.
- showed that excessive rewards for learning tasks can actually lessen students' desire to learn.

- demonstrated that even in localities where crime rates are disproportionately high, neighborhoods can use social controls to reduce crime.
- showed that poverty has distinctive effects on cognitive development for children in single-parent families.

NSF will continue to support an agenda that encourages first-rate research in the social and behavioral sciences to address significant aspects of the human condition. It will pursue that agenda in collaboration with other programs in the agency, with other Federal agencies, and in other sectors.

### **Undergraduate Math and Science Education**

**QUESTION:** The Foundation has devoted a considerable amount of time and energy to improving undergraduate math and science education. Could you provide the Subcommittee with a brief overview of some of those activities? What more remains to be done to help make our young people more comfortable with scientific and technological concepts that will drive our society in the future?

**ANSWER:** NSF provides both leadership in increasing national awareness of problems and opportunities in undergraduate science, mathematics, engineering and technology for all students, and highly leveraged project support. NSF activities as well as program design and support have contributed significantly to a renewed national attention to undergraduate teaching, to increased multi- and interdisciplinary approaches, to fostering coalitions and networks of crucial players, and to the recognition and use of "student-centered" teaching styles to replace the traditional lecture.

Major activities include:

- the Advanced Technological Education program, NSF's contribution to revitalizing the industrial technical workforce;
- Systemic Changes in the Chemistry Curriculum, and the Mathematical Sciences and their Applications Across the Curriculum, designed/intended to foster significant improvements in science and mathematics education for all undergraduate students;
- Teaching Scholars initiative, which provides scholarships for future teachers, and reflects the importance attached to improving the preparation of the next generation of K-12 teachers, particularly among minorities;
- the Alliances for Minority Participation program, which is already producing a measurable increase in the number of minority students successfully completing advanced scientific studies and entering scientific careers;
- the Presidential Faculty Fellowship program, which includes a major component that focuses on teaching improvements involving the nation's best young research faculty;

- the Faculty Early Career Development Program (CAREER) which encourages junior level faculty to link their research projects with their teaching and mentoring responsibilities; and
- the Engineering Coalitions Program, which promotes widespread changes to strengthen undergraduate engineering education.

Grants made in FY 1994 for improving undergraduate education will reach about 12,000 faculty, almost 10% of the full time science and engineering faculty in the U.S. These grants, in turn, will affect more than 750,000 undergraduates.

The educational materials, texts, and software developed with NSF support will impact several million undergraduates, representing a major fraction of the total enrollment in higher education. One example of the impact of NSF support in calculus reform is the Harvard Calculus project whose new formal textbook introduced in 1994 is used by roughly 60,000 students at more than 500 institutions.

The National Science Foundation's efforts to make young people more comfortable with scientific and technological concepts address many of the challenges centered in *Goals 2000: Educate America* and the Administration's goals and strategies stated in "Science in the National Interest". These efforts include:

- improving science and mathematics performance of all students by helping to implement science and mathematics standards;
- improving the elementary and secondary teaching workforce so that they will have the skills and knowledge to instruct and prepare all U.S. students for the next century;
- developing partnerships between the educational community, all levels of government and the private sector; and
- lifelong learning activities which provide the public with the understanding needed to make informed, responsible decisions.

Universities and colleges of all types should be encouraged to undertake comprehensive reform of science, mathematics and technology education that will capitalize on the investments already made and lead to permanent improvements. It is also important to recognize that not all those seeking undergraduate education are younger people, but also adults with extensive life and work experience preparing to change jobs or reenter the job market. Enabling this very diverse population of undergraduates to succeed in a society that is increasingly linked to science and technology concepts is vitally important to the future.

### **Fundamental Research on Teaching and Learning**

**QUESTION:** What percent of the NSF FY 96 budget is devoted the fundamental research on teaching and learning?

**ANSWER:** The FY 1996 NSF budget request has approximately \$3.0 million, or less than 0.10%, devoted to fundamental research on teaching and learning.

Fundamental research on teaching and learning emphasizes the development of basic knowledge about teachers, students, and classrooms. That knowledge ranges from human cognition and science education to ways of assessing mastery of science and mathematics content and process. Activities include research on the description, modeling, and development of learning and the processes underlying human learning such as concept formation development, problem solving, social cognition, attitude formation, motivation, as well as research on teacher attitude, beliefs, knowledge and cognition, classroom characteristics, and conceptual change.

In addition, about \$4 million in FY 1996 funding will support research in cognitive science, concentrating on fundamental research on learning, including such areas as reading, problem solving, and children's conceptions of numbers and of physical and biological phenomena.

### **National High Magnetic Field Laboratory**

**QUESTION:** The partnership between Florida State University, the University of Florida, and the Los Alamos National Laboratory on the National High Magnetic Field Laboratory has seemingly worked very well. Has it been a good investment for the Nation?

**ANSWER:** The National High Magnetic Field Laboratory (NHMFL) promises to be an extremely good investment for the nation. Many technologies depend on research in high magnetic fields or on advanced magnet systems, including magnetic resonance spectroscopies for structural chemistry and biology studies which impact drug design and treatment; magnetic levitation and propulsion; superconducting energy storage, transportation and generation; computers; magnetic separation applied to environmentally important processes; and improved magnetic resonance imaging (MRI) systems.

The laboratory will generate the highest steady-state magnetic fields in the world, providing opportunities for exciting new discoveries in physics, chemistry, biology, and materials sciences and engineering.

The strong commitment by the State of Florida to this project has been a key factor in the rapid development of this unique laboratory. Florida has contributed more than half the total cost and has committed a large number of new faculty and technical staff positions, major equipment and instrumentation, and a building.

### **Reinventing Government: Phase II**

**QUESTION:** Reinventing Government; Phase II: The Administration has announced a phase II to its reinventing government exercise. Is NSF participating? If so, in what way and to what extent do the outyear projections in the president's budget tie back to this activity?

**ANSWER:** The NSF is actively participating in Phase II of the National Performance Review. Accordingly, we are examining all of NSF's basic functions, considering whether the functions should continue to be performed by the Federal Government, how best to do those things the

Federal Government should continue to do, and, in particular, what role NSF should continue to play in performing those functions. Our analysis includes consideration of various alternatives NSF may pursue in order to effectively fulfill the agency's mission within the funding constraints reflected in the President's budget.

## NSF Personnel

**QUESTION: NSF Personnel: Provide a breakdown by directorate of FTE's. Additionally, provide the Subcommittee a breakdown by directorate of the Rotators (IPA's, excepted service, and any other categories) of personnel assigned to NSF and NSF personnel assigned outside the agency (include assignments to other government agencies or departments, universities, and any other categories).**

**ANSWER:** Breakdowns by organization of FTE's, and a breakdown by organization of Rotators and personnel assigned away from NSF, are shown below:

## Breakdown by Organization of FTE's using FTE estimates for FY 1995

ORGANIZATION	FTE
Biological Sciences	113
Budget, Finance, and Awards Management	124
Computer and Information Science and Engineering	64
Education and Human Resources	128
Engineering	119
Geosciences	98
Information and Resources Management	164
Mathematical and Physical Sciences	120
Social, Behavioral and Economic Sciences	139
Staff Office of the Director	86
Office of Polar Programs	48
Coops/Student Aids	23

## Breakdown by Directorate of the Rotators and Personnel Assigned Away from NSF as of 12/94

DIRECTORATE	Rotational Appointments		PERSONNEL ASSIGNED AWAY FROM NSF		
	IPA	VSEE	GOV'T	ACADEMIA	OTHER
Biological Sciences	12	9	2	0	1
Computer and Information Science and Engineering	16	1	0	1	1
Education and Human Resources	35	3	1	0	0
Engineering	20	2	0	0	1
Geosciences	13	2	1	0	2
Information and Resources Management	1	0	2	0	0
Mathematical and Physical Sciences	24	5	1	0	1
Social, Behavioral and Economic Sciences	7	3	4	2	3
Staff Office of the Director	4	0	2	3	0
Office of Polar Programs	4	0	1	0	0

VSEE=Visiting Scientists, Engineering Educators. These are rotational appointments made, under the NSF Act, for up to 2 years. The appointees come from and return to academic institutions.

### Role of NSF in Math and Science Education

**QUESTION: The Role of NSF in Mathematics and Science Education:** Given what the Nation as a whole spends on education, NSF is only a drop in the proverbial bucket. Even in mathematics and science education, NSF is a small player--at least at the K-12 level. What does NSF bring to the mathematics and science education arena that is different and vital when compared to the efforts and expenditures of the Department of Education and the state and local governments?

**ANSWER:** At the K-12 level, NSF operates within a restricted sphere of influence--science, mathematics, and technology (SMT) education. Within this sphere, the Foundation provides:

- vision, leadership, and intellectual guidance through effective collaboration with the professional scientific and technical community, education researchers, practitioners, and school district and state administrators;
- a process of merit review by peer evaluation that promotes success by selecting only the most well-conceived activities and that, irrespective of support, leads to the planning necessary to participate in SMT education reform;
- a comprehensive portfolio of programs that create models of excellence and that work synergistically to build on strengths and create effective mechanisms for the utilization and dissemination of quality, state-of-the-art products to local districts;
- a catalytic mode of operation encouraging leveraging resources from other Federal agencies, state and local governments, business, and foundations that can be directed to SMT education reform at the local level under a system of high accountability for definitive achievements; and,
- prestige that brings status and credibility to state and local efforts.

### Reorganizing the Federal R&D Enterprise

**QUESTION: Reorganizing the Federal R&D enterprise:** There are a number of proposals being developed to eliminate and transfer certain federal R&D activities. For example, one proposal would create a Department of Science and Technology. Another proposal might transfer certain research programs from the Department of Energy to the Foundation. Still a third might eliminate the U.S. Geological Survey and transfer some of its functions to the NSF. What are the issues and questions you believe must be resolved before such proposals are advanced in the legislative arena? What would be the impact on the Foundation and its culture if DOE's high energy and nuclear physics programs were transferred to the NSF?

**ANSWER:** Any large-scale consolidation or transfer of research functions between agencies could have significant ramifications for the future competitiveness and economic health of the United States. The National Science Board (NSB) recently issued a statement, attached,



urging caution when structural changes to the federal R&D system are considered. We at NSF urge that proposals regarding the future organization of federal science assets take these recommendations into consideration.

NSF strongly believes mission agencies such as the Department of Energy (DoE) and the Department of Defense (DoD) must continue to support fundamental research. These agencies are integral parts of a complex and highly pluralistic system of support for research that evolved after the Second World War. In this tightly interconnected arrangement, industry, government agencies and academia each perform complementary roles. Within the federal government, agencies possess unique research and management capabilities critical to their assigned mission. This system remains the finest in the world.

The National Science Foundation is responsible for supporting fundamental science across all scientific disciplines, the only federal agency with such a broad responsibility. NSF's unique mandate naturally leads to close contact and interaction between NSF-funded researchers and several of the DoE national laboratories. For example, NSF funded educational programs—including graduate traineeships and fellowships—help assure a steady stream of top-flight scientists and engineers required for mission-related research. NSF-funded researchers also depend on facilities at many of the DoE laboratories for important fundamental studies in materials science, atomic, high-energy and nuclear physics, and many other areas. Transferring these facilities to the National Science Foundation would have profound consequences on the culture and the mission of the Foundation, and such an action should be studied carefully before implementation.

Several key factors should be weighed before considering changes to the federal support structure for R&D. These include: the degree of overlap between ongoing federal R&D programs; the balance between consolidation and the benefits flowing from the variety of objectives, approaches and cultures inherent in the current system; and the flexibility provided by the current system. Also, questions of accountability to Congress must be answered. Specifically, would consolidation facilitate greater accountability? Would certain areas of research get less scrutiny?

Future funding needs for the national laboratories will be considerable. The national laboratories provide world-class facilities that enable research on the forefront of science. They will require sustained and substantial funding for upgrades and modernization in order to remain at the cutting-edge, irrespective of management or structure.

Changes in the federal R&D complex may be necessary as Congress and the Administration look for ways to reduce the deficit. At the same time, it is critical that we at least preserve—and even enhance—the strength of the current R&D system. In particular, any new alignment must foster coordination and cooperation among complementary federal R&D functions.

NSF is working closely with the other R&D agencies to support research in a more efficient and effective manner under the leadership of the National Science and Technology Council. NSF is also participating in the second phase of Vice President Gore's Reinventing Government Initiative, to achieve cost savings within the existing agency structure. Through these interagency initiatives, we are striving to preserve the many positive features and assets of the current federal R&D system while improving our effectiveness and reducing costs to the American taxpayer.

2/3/95

NSB-95-26

**STATEMENT ON FEDERAL R&D BUDGET REALIGNMENT  
AS ADOPTED BY THE NATIONAL SCIENCE BOARD  
AT ITS 326TH MEETING, FEBRUARY 2-3, 1995.**

The United States is experiencing significant restructuring within industry, government and universities, accompanied by reallocation of the resources that support research and education in the sciences and engineering within all sectors. The National Science Board recognizes that in this time of constrained budgets and changing priorities no Federal program in science, mathematics, and engineering should be beyond careful scrutiny and possible reduction.

However, our nation has come to rely upon a pluralistic approach to support research and development involving an intricate mesh of Federal agencies as well as other sectors of the economy—industry, academia, and nonprofit organizations. The linkages between these constituent parts of our nation's research and technology infrastructure themselves can amplify the benefits from even minor advances in knowledge.

In the process of funding realignment, the abrupt termination of large fractions of the support from any one agency without careful regard for its impact on the health of research in the U.S. can jeopardize the overall government-university partnership for carrying out fundamental research directed to national needs and training the next generation of scientists and engineers.

As one or another Federal agency adjusts its research investment in response to legislated revisions of its mission, it is important that the impact on key national capabilities be considered in a broader context. It is the subtle interplay of Federal support for science and technology that deserves our most thoughtful consideration in this period of budget restructuring, with the goal of protecting our investments and retaining the necessary balance within our national system for financing research.

### High Performance Computing and Communications

**QUESTION: High Performance Computing and Communications: What is the NSF role in the high performance computing and communications program and what notable or important accomplishments can you point to that have made or will make a difference in the lives of taxpayers? What is the appropriate role for the Foundation in the HPCC program?**

**ANSWER:** As a major player in the interagency HPCC program, NSF carries out core functions in basic research and human resource development, and coordinates the broad deployment of the National Research and Education Network (NREN).

The Foundation's objectives are:

- generating fundamental knowledge with the potential for radically changing the state of high impact computing and communications;
- supporting fundamental research to make advanced computing and communications information infrastructure available to a larger segment of society to solve information intensive national challenges and to advance educational technologies;
- researching and prototyping new generations of scaleable parallel high performance computers and software technologies;
- creating a cadre of scientists, engineers, and technical personnel prepared to employ these new capabilities in academia and industry;
- creating interdisciplinary teams of scientists, to create innovative computational and communications technologies that support overarching engineering, scientific and societal goals; and
- encouraging partnerships to enhance innovation, technology transfer and U.S. productivity and industrial competitiveness.

Some examples of the significant impact of the HPCC program include:

#### *NSFNET*

The NSFNET program is a major component of the Internet, the network component of the National Research and Education Network (NREN) program. Very simply, the Internet -- once of interest only to the nation's research community -- is explosively spilling over from its original research and education functions in dramatic and unanticipated ways.

Before 1985 relatively few scientists were network users. Collaborations between colleagues in different institutions were difficult, time-consuming and costly. As NSFNET and the associated regional networks grew and extended connectivity throughout research and education institutions in the U.S., scientists quickly discovered and exploited the ease with which they could communicate with their colleagues, exchange data and results, and seek out new information. By 1990 Internet connectivity was an essential tool for the conduct of scientific research. Multi-institute and multi-disciplinary research is becoming increasingly commonplace, with barriers disappearing between institutions and disciplines.

The humanities disciplines and libraries are also making use of research networks in a major way. Now basic network information is readily available; information searches, document

retrieval and information retrieval are carried out routinely throughout the Internet world, and journals and newsletters are proliferating on the Internet. Libraries are making increasing amounts of information available electronically, and state-initiated access to NSFNET and the Internet for the precollege education community is becoming increasingly common.

Because of the tremendous commercial success of Internet service providers, by the end of Fiscal Year 1995, the vast majority of support for the Internet will be provided by the private sector. Through 1999, NSF will continue to provide a very limited amount of support to ensure that the network continues to operate smoothly.

There has also been considerable impact on the computer and communications industry. As noted, NSFNET stimulated the rapid deployment of regional networks throughout all 50 states. The market potential demonstrated by this growth led to the establishment of a new business area, Internet routers. One consequence of that has been the emergence of the US as the clear world leader in data communications networks, both in the use and deployment of networks and in the development of network technology.

The Foundation's role, in cooperation with other federal agencies, is to support long term fundamental research and education activities in computer, communications, and information sciences and technology. Recognizing that information technology is increasingly central to our society, NSF must provide access to emerging leading edge computing and communications technologies required for conducting long term fundamental research. These technologies are critical to ensuring the development of new knowledge and technologies necessary to retain the nation's leadership in the vital area of applications of information technology.

#### *Research*

Research in high performance computing has led to many important applications which include:

- Virtual environments are being applied now in medical science -- creating new areas of study for pre-operative analysis of procedures and for training of medical personnel; and
- A software tool -- the Rapid Interconnect Circuit Evaluator (RICE) has found use by a number of companies including Texas Instruments, IBM, Intel and Motorola. It has been used to reduce the evaluation times for large gate array designs from 72 CPU hours to 20 minutes, while simultaneously providing increased accuracy.

#### *High Performance Computing*

The NSF Supercomputer Centers, originally established to provide researchers in universities access to state-of-the-art computing and communications capabilities, have, through leveraging NSF funds, expanded their influence far beyond the academic research community. Not only do they have a significant impact on the conduct of science in a broad range of disciplines by providing reliable high performance computing services, but they educate and train students and scientists in the appropriate and effective use of advanced high performance systems and methods. As part of their activities, the Centers develop and freely distribute tools and software for high performance computing, one of the most prominent of which is MOSAIC, the first simple to use software for navigating on the Internet. The Centers pioneered partnerships with the private sector to introduce HPCC technologies and practices to solve specific design and manufacturing problems.

### *Education*

The recent opening of the Math and Science Gateway at the Cornell University Theory Center provides a dramatic demonstration of how scientific images and collaborative tools that are available through the national information superhighway can be used effectively in the teaching and learning of science and mathematics to students in grades 9 through 12. Through the Gateway, students and teachers can find clear explanations of the latest El Niño observations, get expert volunteer help with their math problems, or search for information on such important scientific programs as the Human Genome Project. In addition, the Gateway includes an extensive section for educators, with links to information on curriculum, lesson plans, software for the classroom, and how to set up web servers in schools.

### **Manufacturing**

**QUESTION: Manufacturing: The FY 96 budget proposes to spend \$135 million (a 6% increase) in NSF support for manufacturing. What is the NSF role in manufacturing? Why isn't this R&D better left for the private sector to support? What can NSF possibly contribute in this area?**

**ANSWER:** Manufacturing is a complex activity that integrates knowledge from many disciplines. This integrated aspect makes the predictable solution of problems in manufacturing complex, even for producing simple products. The fundamental understanding of most manufacturing processes is not refined enough to allow them to be improved using a rational, systematic approach. Therefore, individual firms may solve problems by trial and error, with little transfer of knowledge among firms and little confidence that the problem will stay fixed. NSF-supported research projects create new fundamental knowledge and new methodologies that enable industry to build more effective (usually computer-controlled) manufacturing systems and enterprises and lead to the creation of new technologies and new industries.

NSF also has a role in manufacturing education that is to build competence in synthesis and integration that will better prepare students for the jobs they will need to do in manufacturing. As industry continues to move away from standard mass production toward rapidly reconfigurable, flexible enterprises, workers will need to become more flexible and innovative as well. NSF support enables broad educational reform through experimental projects and dissemination of strategies that result in success. In both research and education programs, NSF seeks guidance from industry on long-term direction and encourages university researchers to choose fundamental problems that are relevant to industry's long-term, generic needs.

The complexity of manufactured products and processes in all industry sectors continues to grow rapidly, and the rate at which new innovations transform and displace whole industries is accelerating. Most U. S. industry investments in manufacturing have been directed at specific product development rather than process innovation. Moreover, competitive pressures and financial incentives drive companies to focus on short-term incremental improvements in their existing approaches to manufacturing. NSF's support of fundamental research and education creates an intellectual infrastructure and a supply of graduates who understand the current state-of-the-art from which industry can draw expertise and insights. NSF investments in high-risk, peer-reviewed fundamental research stimulate open competition among researchers, with

the resulting knowledge accessible to every company. This open system enables the highest quality research in a form that no company's focused in-house staff could produce.

NSF has contributed and will continue to contribute effectively to the base of fundamental knowledge upon which successful manufacturing innovations have been built. Examples of NSF-supported research include:

- Computer-Aided Design (CAD) systems allow mechanical designers to create geometric models of the parts that they want to produce using computer graphics. One advantage of these digital descriptions is that they can be interpreted to produce instructions that computerized, numerically controlled (NC) machine tools can use to make hardware.

In 1972, the NSF funded the Production Automation Project under Professor Herbert Voelcker at the University of Rochester to invent software to perform this automatic programming function for NC machine tools. The first major discovery of the study was that no adequate mathematical and computational means existed for unambiguously describing mechanical geometries. Thus, the research focus of the project was turned towards laying the groundwork for the discipline that is today known as "solid modeling."

By 1975, the theoretical groundwork was complete and by 1976 an integrated solid modeling system with limited capabilities was completed. During the next five years a number of improvements were made to the system and software was developed for use by industry. This phase of the research was supported jointly by NSF and industry. The software system was widely adopted, with over 1000 licenses issued and widespread implementation by industry. For example, it formed the core McDonnell-Douglas Automation's UNISOLIDS CAD system and was licensed by AutoDesk for use in AutoCad, the most widely used CAD software in the world. Today, essentially every commercial CAD system includes elements of the fundamental breakthroughs that were initially supported by NSF.

- In a second example, Professor George Nemhauser of the Georgia Institute of Technology was funded by NSF for a period of three years in 1992 at a level of \$500,000 to perform his research concerned with the modeling and solution of mixed integer programming problems. Mixed integer programming is an approach that uses mathematical techniques to represent and solve classes of problems commonly encountered in areas such as business, manufacturing, health care, physics, defense, etc. Integer programming problems typical of the sizes encountered in real life problems are difficult to solve and are very computationally intensive. Using a new modeling technique, Professor Nemhauser developed a solution approach which he also coded into software. With the software package, models that normally take in excess of 100 hours of CPU time on mainframe computers using the best commercially available codes can now be solved to optimality in less than an hour.

Delta Airlines now uses the software in scheduling its fleet of airplanes daily. It is reported that the airline saves, on the average, \$100,000 per day in scheduling its flights. American Airlines also uses the same software package in scheduling its fleets. Other companies that have used the software that resulted from this research include IBM, in the design of compilers, Baxter in the management of distribution problems, and AT&T in scheduling the production of fiber optic cable.

### Balanced Increases Throughout Budget

**QUESTION:** Balanced increases throughout the budget: In looking over the budget request we see that research is up about 7.6%. Each of the research directorates is up between 6.5% and 8.5%; each of the research initiatives in the various strategic areas is up between 6% and 8%. Some would say this is an example of spreading the wealth evenly and avoids setting tough priorities either between disciplines or between strategic areas. Can you tell the subcommittee a bit about the process you went through to allocate your FY 96 request among and between disciplines and initiatives?

**ANSWER:** Significant changes in activities within and between directorates or strategic areas, particularly at the program level, may be masked when looking at changes in the aggregate. NSF's FY 1996 budget request was developed through a lengthy and deliberative process which involved staff throughout the Foundation. In general, NSF priorities and budget allocations are influenced by such factors as scientific and engineering readiness, technical feasibility, affordability, and balance with existing programs. These priority-setting factors are debated continuously through such mechanisms as advisory committees, the National Science Board, professional societies, the National Research Council, workshops and task forces.

NSF staff evaluate their programs and justify their recommended budgets to the Director and the National Science Board. Staff also propose yearly initiatives and areas of special emphasis. There is constant discussion within NSF over which areas to emphasize in program announcements and solicitations and how much is needed to support these new directions.

Within each of NSF's strategic areas, a coordinating body of NSF staff develop a profile of the area, its key research areas, the overall budget base for the area, how existing resources are distributed among the organizational units, and how existing or additional resources might be used most effectively. Based on the work of the coordinating groups, NSF senior staff discusses budget allocations within and among the strategic areas, making recommendations for allocations to the Director and Deputy Director.

Specifically, development of the FY 1996 request began early in 1994 when initial planning efforts got underway. These plans were presented and discussed at a meeting of the National Science Board in June 1994 that was devoted to planning and developing NSF priorities. Through the summer of 1994 planning efforts continued, including an examination of ongoing research commitments, scientific plans, emerging opportunities, and disciplinary needs within the context of available funds. These planning efforts led to the development of a draft of the FY 1996 request which was presented to the NSB over the summer of 1994, and eventually to development of the FY 1996 request to Congress.

### Future Supply of Scientists and Engineers

**QUESTION:** Dr. Lane, what is your view with respect to our future needs for scientists and engineers. Will we have enough?

**ANSWER:** Scientifically and technologically trained people are an invaluable national asset -- a foundation of strength that enables the nation to pursue a great variety of opportunities. Professional scientists and engineers anchor the scientific and technological workforce and are indispensable to promoting growth and innovation throughout our economy.

As the report, *Science in the National Interest*, emphasizes, "our principal resource for maintaining leadership in fundamental science and engineering and for capitalizing on its advances is our talent pool of well educated scientists and engineers....Because training scientists is a long process, we cannot quickly overcome shortfalls in trained personnel in some areas and should not react precipitously in allocating our training support."<sup>1</sup>

Today, it is well known that young scientists and engineers are facing difficulties in the job market. The National Science Board's most recent version of *Science and Engineering Indicators* explains that: "...in the early 1990s, the recession, defense-related spending cutbacks, reduced research and development budgets, and industry downsizing all took their toll on S&E employment."<sup>2</sup> Because of this, NSF is working with universities, industry, and other agencies to explore ways to broaden the education and training of future scientists and engineers. For example, NSF's GOALI program (Grant Opportunities for Academic Liaison with Industry) allows faculty and students to collaborate on projects with researchers from industry.

In summary, there is no simple answer to the question, "will we have enough?" On the one hand, it is folly to believe our nation could possibly have too many highly skilled individuals. On the other hand, the current realities of the science and engineering labor market require that we revisit and reassess our system of educating scientists and engineers, especially at the graduate level, in order to help students prepare for and seek a wider variety of career opportunities.

### Global Change

**QUESTION:** Global Change: What is the NSF role in the Global Change program and what notable or important accomplishments can you point to?

**ANSWER:** NSF is one of a dozen agencies participating in the U.S. Global Change Research Program (US/GCRP), an interagency effort that coordinates activities designed to produce a predictive understanding of the integrated Earth system. Foremost among the problems for which the US/GCRP seeks to advance fundamental knowledge are long-term climatic change, seasonal and interannual climate variability, and changes in stratospheric ozone and other aspects of atmospheric chemistry. Major foci of the US/GCRP have been to observe and

<sup>1</sup>Executive Office of the President, Office of Science and Technology Policy, *Science in the National Interest*, August 1994, page 25.

<sup>2</sup>National Science Board, *Science and Engineering Indicators-1993*, (NSB 93-1), page 61.



record what has been happening to the Earth's environment; to understand why changes are occurring; and to improve predictions of what changes will occur in the future. NSF's global change research budget in FY 1995 is \$169 million.

The primary emphasis of global change research at NSF has been the support of activities that advance fundamental understandings of the complex interactions among different facets of the Earth system. This includes studies of the impacts of biological and human systems on the physical systems of the Earth, interactions among the different physical systems, and analyses of the consequences of physical system change on biota and people. NSF also has encouraged advancement of modeling activities designed to improve representations of Earth system interactions, and it has supported activities that facilitate data acquisition and data management necessary for basic research on global change. As part of its efforts to advance knowledge of interaction among different systems, NSF has supported research on the advancement of methods for conducting integrating assessments and on research that examines the processes used by organizations to identify and evaluate different types of policies for mitigation, adaptation, and other responses to changing global environmental conditions.

Among recent accomplishments and new findings from NSF-sponsored global change research projects are the following:

- The Tropical Oceans-Global Atmosphere (TOGA) program, one of the first projects conducted under the auspices of the U.S. Global Change Research Program, was successfully completed in 1995. A ten-year project, TOGA produced fundamental new knowledge about the processes that link the tropical Pacific Ocean with the global atmosphere. TOGA researchers applied that knowledge to the first-ever successful 12-month-in-advance predictions of seasonal variations in sea surface temperatures in that area, which are highly correlated to extreme weather and climate anomalies around the world. These predictions are now being issued regularly by several nations, including the U.S., and are being used in planning for agricultural and water sectors of national economies.
- A very realistic numerical model of the three-dimensional global ocean circulation, including important strong currents and eddies and proper representation of coastlines and bathymetry, was developed in order to improve understanding of physical ocean dynamics and to enable more accurate prediction of climate change. The model output was compared with both in-situ and satellite observations and was found to be in very good agreement with what actually happened. The agreement of predicted surface height variability with that observed by NASA's new TOPEX POSEIDON satellite altimeter was especially impressive. Output from this model was distributed to more than thirty research groups worldwide for further analysis and additional scientific uses.
- The Equatorial Pacific Process Study phase of the Joint Global Ocean Flux Studies moved into a data-synthesis and -analysis stage, with new insights gained into the dynamics of primary carbon production associated with the upwelling of waters in this region. Both primary productivity and chlorophyll were found to be lower than expected for this high-nutrient area, with analyses of carbon and other chemicals at different depths and under different conditions indicating that the food web was driven by ammonium rather than nitrate. The spatial distribution of dissolved iron suggested that this micronutrient entered

the food web both from upwelling and via atmospheric deposition, thereby suggesting that current popular notions about iron limitation in this region should be re-examined.

- A two-ship, two-month-long crossing of the Arctic Ocean by surface vessels in 1994 provided a broad interdisciplinary base for assessing the role of the Arctic Ocean in regional and global climate and environmental systems. Preliminary measurements of phytoplankton and their nutrients suggested that the Arctic Ocean was a far more productive area than had been previously thought, and hydrographic measurements suggested that the influence of the Atlantic Ocean on the central part of the Arctic Ocean was much larger than suspected from historical data. These data provide valuable new information to refine ocean circulation models and to improve models of carbon exchange for polar regions.
- A prototype model for Lake Erie has been expanded to the entire Great Lakes system, linking hydrologic, environmental, and socioeconomic models in a simulated environment. Interactive socioeconomic consequences of the biophysical changes associated with climate change are emphasized in the simulated environment. This prototype is being further refined and integrated with a decision model to understand the policy implications of lake management options for commercial navigation, hydroelectric power, ecosystems, flood damages, recreation, and other issues. This integrated framework will organize and make available to decision makers necessary information to deal with the impacts of climatic changes.

## GLOBE

**QUESTION:** GLOBE: What is the NSF role in the GLOBE program and what notable or important accomplishments can you point to that have made or will make a difference in the lives of taxpayers? What is the appropriate role for the Foundation in the GLOBE program?

**ANSWER:** The GLOBE Program is a hands-on, technology-based program involving K-12 teachers and their students in a science-education partnership effort to monitor and understand planet Earth. Students take measurements and collect data as part of a network that allows scientists to investigate global environmental changes.

NSF serves on the GLOBE leadership council and steering committee, and provides focus and leadership for the programs in science, education, and information/communications technology. The Foundation also provides access to the science, education, and technological communities relevant to GLOBE.

In Phase I of GLOBE efforts, NSF supported education activities through the University Corporation for Atmospheric Research (UCAR). In Phase II, an Announcement of Opportunity for Science and Education Teams was issued, sponsored jointly by NASA, NOAA, and NSF. NSF coordinated the merit review process, and pending available funds, final award decisions are expected within the next few weeks.

The benefit of the GLOBE Program, and the ultimate gain for taxpayers, will be that children will be better prepared for the technology-rich environmental world that exists as they leave school.

This will be particularly important as they make their transitions into the workforce and compete for jobs. These activities ultimately will enable students to make more informed decisions about environmental issues in the nation as well as their own communities.

### **Indirect Costs**

**QUESTION: Indirect Costs:** The Administration has published new draft guidelines for reimbursement to colleges and universities of indirect research costs. Would you describe the major changes proposed by the Administration and what you hope to accomplish with these new regulations? In what way was the university research community involved in this process?

**ANSWER:** We believe the new A-21 guidelines focused on total research costs will result in more consistent treatment of research costs (principally indirect costs) across institutions and may eliminate some of the contentiousness that has arisen in this regard between academic institutions and the Federal Government. Areas such as special studies for utility, library and student services costs, dependent tuition costs, and interest costs have been handled differently by institutions and have resulted in the perception of inequitable variances in administrative or facility cost rates. We are also hopeful the change in terminology from "indirect costs" to "administrative costs and facilities costs" may result in better recognition that these costs are, in fact, real costs which are necessary for the successful conduct of research.

NSF supports Administration initiatives which promote equity, consistency, and simplicity in the way the costs of Federally-sponsored research are reimbursed at colleges and universities. The Administration has proposed six areas for further review.

With respect to the university research community involvement with these recommendations, OMB and OSTP hosted two major meetings involving university representatives, research societies and organizations and major federal funding agencies. University concerns and recommendations resulting from these meetings were considered by OMB prior to formulation of the new draft guidelines.

### **Authorization for National Research Facilities Construction Projects**

**QUESTION:** The Science Committee's NSF authorization bill which passed the House last year included a provision requiring that all national research facilities construction costing more than \$50 million be explicitly authorized. How would such a provision, if enacted into law, affect the NSF planning and approval process for new facilities construction and major upgrades to existing facilities? What is the earliest point in the approval process at which Congress could be notified of the intent by NSF to seek OMB approval for facility construction funds in an NSF budget request?

**ANSWER:** Congress is usually made aware of potential plans for major facility construction activities at several early points in the Foundation's planning process. NSF's current procedures for developing and approving major facilities projects call for substantial planning efforts prior to the decision to initiate construction -- often lasting several years -- including extensive discussions with relevant portions of the science and engineering community,

external studies and reports, and internal NSF review and study. Procedures for these planning activities have been in place for many years. These procedures were reviewed and strengthened last fall, and will guide the development of projects that could potentially be supported by our Major Research Equipment account. Funding for this planning phase comes out of program funds, and information on these planning activities is generally made available well in advance of any request to either OMB or to the Congress for actual construction funds.

When planning has reached the stage that a clear picture of the costs and the benefits of the project has emerged, the project must be reviewed and approved, first by the NSF Director, and then by the National Science Board (NSB), in order for further work on the project to proceed. NSB approval is required prior to a project's inclusion in the Foundation's budget request to OMB and subsequently in the Congressional budget request. It is important to note, however, that not all planning efforts or projects which receive approval from the National Science Board are included in the Foundation's budget or actually proceed to the construction phase.

In principle, requiring that the construction of all major research equipment projects that exceed a certain dollar threshold be authorized would not affect the Foundation's planning process. However, we are concerned that requirement of the explicit authorization of a major research equipment project would hinder the management flexibility we need to balance competing priorities within the overall resource constraints that we must confront. In addition, we are concerned that the requirement for the explicit authorization would hinder our ability to respond rapidly to an emergency situation. Therefore, we are not in favor of the authorization requirement.

### Education Systemic Reform

**QUESTION: NSF has placed great emphasis on its efforts to stimulate systemic improvements in science and mathematics education in the States--the Statewide Systemic Initiative. Can you provide us with an assessment of the value of this approach to science education reform? What have we learned thus far?**

The Statewide Systemic Initiative (SSI) Program challenges states to undertake long-term, comprehensive reform initiatives that will raise U.S. student achievement to levels that are internationally competitive. These reforms include development and implementation of ambitious learning goals for students, more coherent state and local education policies in support of these goals, increased collaboration and resource sharing among agencies and institutions, new assessment techniques to measure student performance, and opportunities for teachers to significantly enhance their knowledge of mathematics and science content and pedagogy.

The primary value of a systemic approach is that it provides states with an agenda for reform that involves broad segments of the community. States are then able to provide more focus to reform efforts and coordinate resources more effectively. States employ a number of strategies to implement systemic reform: state curriculum frameworks, assessments, professional development, reform of preservice education, and public information. All these are undertaken with the ultimate intention that there will be changes in the delivery of instruction and student achievement in mathematics and science.

More specifically, at the approximate mid-point in the Program, we have learned the following:

- Visions of good practice in the form of curriculum frameworks or other documents are extremely important in helping set direction for mathematics and science education at the district and school levels. All the SSI states are developing or revising state frameworks that incorporate more active student learning, greater concentration on thinking and problem solving, and increased use of technology in the classroom. At this point, 1/3 of the states have developed detailed visions of good practice in mathematics and science education.
- The SSI Program is designed to be a catalyst for state and local reform. States are building capacity for continuation of professional development through various approaches such as regional centers, working with established systems of professional development providers, and building the technology infrastructure. Other states have created new, nonprofit institutions designed to increase the capacity of the mathematics and science system after NSF support terminates.
- Approximately 37% of SSI funds support professional development for teachers. SSIs provided professional development to more than 76,000 teachers during the past year, representing 13% of the public school teachers in those states. Collectively, these teachers impact over 600,000 students.
- Another critical component of systemic reform is revised teacher preparation programs. Some SSIs are working to restructure preservice education, redesign undergraduate mathematics and science programs, and strengthen higher education/school district partnerships. The approaches they develop can be used with other states.
- One hallmark of the degree to which an SSI is systemic is the degree to which other resources can be leveraged in support of SSI goals. During the past year, states have leveraged over \$83 million in funds from other sources.
- Finally, the SSI Program has provided a model for the Department of Education's Goals 2000 program, requiring an overall plan including participation by stakeholders, curriculum frameworks and assessments, intensive professional development, and coordinating resources. We anticipate that what is learned from the SSI Program will be broadly applicable to Goals 2000 and to states which have not received SSI funds.

#### NSFNet Transition

**QUESTION:** NSF is now in the process of withdrawing support from NSFNet, the national research and education computer network that has been the major federally sponsored component of the Internet. Where are we in this transition process; are there any serious problems that could result in deterioration of network support in the research and education communities?

**ANSWER:** NSF is changing how it provides support for the national research and education network in order to take advantage of the private sector networking services now available. The change, which is the separation of commodity-level internet traffic from experimental

leading-edge services, is scheduled to take place by the end of April 1995. The purpose of this change is to use government funds in non-commercial areas, and to have the private sector provide what have become the commodity parts of the internet.

The NSFNet Program will continue to support the exploratory research and education aspects of networking development, including facilities for experimental high-bandwidth applications, research on new protocols, and efforts to help solve the technical problems arising from the growth of the Internet.

In order to ensure that the transition process takes place with no disruption in service, NSF is providing regional networks assistance funding through 1999. Although no longer providing full support for the Internet, until 1999 NSF will continue to fund four Network Access Points to ensure interchange of traffic among the various private sector network access providers, and will support routing services to ensure that the Internet continues to operate smoothly.

### Academic Research Facilities

**QUESTION:** The current estimate for modernization of inadequate academic research space is between \$6 and \$10 billion. NSF supports approximately 25% of all federally sponsored, university-based research. What is the appropriate share of the cost of meeting the facilities need within a reasonable period of time?

**ANSWER:** While NSF funds 25% of all basic research performed at universities and colleges, it is important to note that mission agencies also rely on academic institutions to conduct much of their research and development activities. As a result, NSF funds approximately 15% of all federally supported R&D performed at universities and colleges.

If one were to assume that NSF should respond to about 25% of a \$6 billion total facilities (bricks and mortar) need, then over a ten year period, NSF's "share" would be \$60 million per year. (This assumes the current level of cost sharing by proposing institutions.) However, this calculation is based on the questionable premise that Federal agencies each support different and separable segments of the research community, and that the facilities problem can be solved "agency by agency". It also assumes that the Federal government should be expected to meet this entire need, when in fact the Federal role in this arena is fairly small.

Although NSF funds a portion of the federally-sponsored university-based research activities in the United States, the Foundation does not support a separate, identifiable portion of the research community. The institutions, facilities, and investigators that are supported by NSF's research programs are also supported by other Federal R&D agencies, because their research activities are multifaceted and interconnected. For example, a research facility may have multiple uses for research that are supported by several agencies. An individual investigator may study a phenomenon at a very fundamental level using NSF support, while also exploring its technological implications with support from another Federal agency. Therefore, it is not possible to estimate that portion of the Nation's academic research infrastructure needs that is NSF's "share", as distinct from the share for which other agencies are responsible.

Despite this interconnectedness of resources and needs, NSF has begun the process of addressing the shared interagency problem of infrastructure renewal in two ways. First, NSF has established a highly visible and successful program for facilities modernization. NSF's Academic Research Infrastructure Program has made a total investment of more than \$205 million in facilities modernization since Fiscal Year 1991, including \$59 million planned for Fiscal Year 1995. Together with the non-Federal cost sharing provided by proposing institutions, the ARI Program has catalyzed a total facilities investment of approximately \$500 million to date.

NSF has designed the Academic Research Infrastructure (ARI) Program to meet the highest priority facilities needs of the research community. Cost sharing at a level of 50% is required from all Ph.D. granting institutions, and 20% is required from all nondoctoral institutions. Each institution is limited to two proposals per year. These regulations help to ensure that submitting organizations set priorities carefully. Proposals to the ARI Program are subjected to a rigorous merit review process that evaluates each proposal's scientific merit, potential for impact on research and research training, the commitment of the submitting institution, and the technical quality of the facility's plans.

NSF seeks to distribute ARI funding fairly across types of institutions and geographic regions. For example, the competition for facilities support is stratified into three separate competitions, based on the amount of NSF funding each institution has received in recent years. Proposals have been submitted from all 50 states, and facilities have been supported in all states except two. In addition, NSF is committed to investing a minimum of 12 percent of the Program's funds for facilities modernization at minority institutions, including Historically Black Colleges and Universities.

Second, NSF is actively involved in an effort to design an interagency solution to the shared problem of infrastructure renewal. NSF will have the greatest impact on the facilities problem if it acts as part of an interagency effort. The Foundation believes that the key to making wise future investments in academic research infrastructure is the establishment of interagency guidelines for collaboration. These guidelines should build on NSF's traditional strength -- competitive merit-based grants programs -- and should evolve into multi-agency programs that make cost-effective investments in non-redundant, high-opportunity facilities. This approach will help to ensure that, while the Federal government plays a relatively small role in funding facilities, the Federal investment in academic research infrastructure is guided by scientific merit, high priority need, and potential for contributions to science and society.



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March 20, 1995

The Honorable Steven H. Schiff  
Chairman, Subcommittee on Basic Research  
Committee on Science  
U. S. House of Representatives  
Suite 2320 Rayburn House Office Building  
Washington, D. D. 20515-6301

Dear Congressman Schiff:

I am pleased to respond to your letter of March 14, 1995 requesting my answers to questions posed by Representative Joe Burton. In the following, I will indicate Representative Barton's questions in italics and my comments in normal text.

*1) Recently two reviews of the DOE National Laboratories were completed. One of the reviews was conducted by the General Accounting Office and the other was conducted by the Secretary of Energy Advisory Board, headed by Robert Galvin. What functions, if any, do you think the National Science Foundation (NSF) can undertake that are currently being done by the DOE National Laboratories?*

My brief answer is "virtually none". NSF is basically an agency that awards grants and contracts, based on relevance, originality and merit, to individuals or groups engaged in scientific research or education. The DOE National Laboratories are mission-oriented, operating laboratories that do scientific research and development. The two missions are quite different. Moreover, in my view it is easier for an operating laboratory to expand its scope into extramural grants and contracts than for the reverse transformation. Thus, I believe NSF, which fulfills its present mission superbly, is ill equipped to assume responsibility for operating laboratories. Moreover, to attempt to do so would threaten its ability to fulfill its present mission.

*Specifically, I would like your opinion on the outcome if NSF were to be restructured in the following two ways:*

*A) NSF assumes the Basic Research and High Energy Nuclear Physics missions from DOE.*

These missions would be less threatening to NSF than taking over the National Labs, and NSF could probably do a good job. However, from the nation's point of view the question is how important is a secure future energy supply. If it is not deemed of sufficient importance to retain a federal agency devoted to it, then it might be satisfactory to transfer the responsibility for maintaining "strategic programs" of research in energy supply and use to NSF. If, on the other hand, a secure energy supply, is deemed a national priority - similar to defense, space, health, and environment - and an agency to address that mission is retained, the research associated with that mission should remain with the responsible agency.

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President Emeritus - Rensselaer Polytechnic Institute  
Senior Vice President (Ret.) - Science & Technology - General Electric  
Chairman - Board of Governors - American Institute of Physics



B) NSF, further, assumes the non Defense laboratories and their missions..

As above, I do not believe this would be desirable, and, in fact, would be detrimental to the important, central mission of NSF of today as well as resulting in a poor job of running the laboratories.

2) As you know, Congress is going to seriously consider changing the mission statements of the DOE National Laboratories, including privatization and possible termination of their assets. Also, there is a real possibility of restructuring or possibly eliminating the Department of Energy. What assets of the DOE National Laboratories, and what activities of DOE might NSF better utilize?

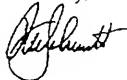
I believe that the assets of the DOE National Laboratories and the activities of DOE that might be better utilized by NSF are very limited. There might be some very specific items that could be identified by a detailed look at programs but I do not believe this is a strategy that will contribute very much to solving the problem of what to do with the National Labs if DOE is eliminated.

3) And finally, what is your opinion of a "Department of Science and Research". Or a "Department of Science and Technology" that combines the National Institutes of Health, NASA, and some of the research functions of DOE, with NSF being a key leader?

While this proposal might have some attractive features - e.g. making it easier to establish priorities across many fields of science - the disadvantages far outweigh the advantages, in my view. Having spent 37 years in a highly successful corporate lab, I know the importance of supporting specific missions and objectives with the research needed to succeed. Thus, I strongly believe that any government mission that warrants the existence of an Agency devoted to that mission must be held responsible for supporting research appropriate to that mission. I am therefore opposed to splitting out the research of mission oriented agencies and putting it under a central agency. The mission of NSF, of course, is to fulfill the long standing commitment of the federal government to basic and exploratory research, especially in our colleges and universities, and to the education of the scientists and engineers needed by our high tech society. NSF should cover national research needs not covered by mission agencies.

I hope that these remarks will help your Subcommittee in its important deliberations.

Sincerely,



## MEMORANDUM

**TO:** Cheryl Faunce, FAX 226-6983  
**FROM:** Erich Bloch  
**SUBJECT:** Response to Questions submitted by Rep. J. Barton  
**DATE:** March 20, 1995

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I am pleased to submit answers to the three questions submitted by Rep. Joe Barton (TX):

1. NSF is well positioned to assume the responsibility for some of the DOE laboratories.

In particular, **Restructuring Proposal A** of question #1 would complement the mission and strengths of NSF. NSF is naturally suited to assume the management of:

- Lawrence Berkeley,
- Fermilab,
- Stanford Linear Accelerator (SLAC) and
- Brookhaven.

These labs have several common denominators:

(1) They are predominantly concerned with basic physics research.

(2) They are user facilities, whose primary, but not exclusive, customer is the academic community.

(3) They are managed by academic contractors or academic user groups. This is similar to the management of the Cornell Electron Storage Ring (CESR), a high energy physics lab at Cornell, the National Center for Atmospheric Research (NCAR) in Colorado, and the astronomy labs, all of which are NSF responsibilities. (The NSF organic act forbids NSF from directly managing any laboratory.)

(4) NSF is an important player in high energy physics research, and I always have been of the view that more cohesive strategies and greater efficiencies could be achieved if the support for that field were concentrated in one agency.

With regard to **Proposal B**, I believe that assigning the

non-defense labs to NSF, in addition to the laboratories mentioned above, would overload the agency and give it responsibilities for which it does not have the necessary background. As an example, Pacific Northwest Laboratory (PNL) has responsibility for the R&D required to clean up the Hanford site and Argonne has major responsibilities for fission reactor design and evaluation. These areas are completely foreign to the activities and prime mission of NSF.

My preference would be to place PNL, Argonne, Oak Ridge, the National Renewable Energy Laboratory (NREL) and Idaho National Energy Laboratory (INEL) under a new independent agency with a common mission for "Technology Research."

2. Answers to Question 1 deal with this issue.

3. I have been involved in this question on and off for over 10 years, and I have not been, and I am not today, convinced of the need for such a major change. Some of the issues that concern me include the following:

a. The only advantage of such a department would be its potential to construct and carry out a coherent science and technology strategy. The same coherence could be obtained by a more active Office of Science and Technology Policy (OSTP) without the added inefficiency of size.

b. The department would have the largest budget of any department, save DOD and HHS. It would, therefore, present an inviting political target for those skeptical of the value of R&D.

c. It would take many years for the department to function properly. (The reorganizations that led to the creation of the departments of Energy and Education are instructive in this regard.)

d. Much of Federal R&D spending is performed in support of agency missions. Separating the research from the driving mission could be counterproductive.

If a new science and technology entity were to be created:

a. It should not include more than the non-defense laboratories of DOE, the DOC science and technology missions, and the various research activities of Transportation, Agriculture and Interior. (Even this could create problems because of the heterogenous nature of their research.)

NSF and NIH definitely should not be included. Making

them a part of such an agency would detract from their basic research missions and subjugate their long-term activities to day-to-day concerns.

b. It should be an independent agency rather than a cabinet-level department to avoid excessive politicization.

c. Congress must limit the number of committees with jurisdiction over it. Otherwise, the new science and technology agency would be overseen by literally dozens of Congressional committees, and the burden its management would have to carry would be onerous, jeopardizing the effective discharge of its mission.

Mr. Erich Bloch  
March 8, 1995

Questions Submitted by Representative Joe Barton (TX)

- 1) Recently, two reviews of the DOE National Laboratories were completed. One of the reviews was conducted by the General Accounting Office, in which you participated, and the other was conducted by the Secretary of Energy Advisory Board, headed by Robert Galvin. What functions, if any, do you think the National Science Foundation (NSF) can undertake that are currently being done by the DOE National Laboratories?

Specifically, I would like your opinion on the outcome if NSF were to be restructured in the following two ways:

- A) NSF assumes the Basic Research and High Energy Nuclear Physics missions from DOE.
  - B) NSF, further assumes the non Defense laboratories and their missions.
- 2) As you know, Congress is going to seriously consider changing the mission statements of the DOE National Laboratories, including privatization and possible termination of their assets. Also, there is a real possibility of restructuring or possibly eliminating the Department of Energy. What assets of the DOE National Laboratories, and what activities of DOE might NSF better utilize and conduct?
  - 3) And finally, what is your opinion of a "Department of Science and Research," or a "Department of Science and Technology" that combines the National Institutes of Health, NASA, and some of the research functions at DOE, with NSF being a key leader?

**Statement of Dr. Frank H.T. Rhodes****Chairman****National Science Board****For the Hearing Record****House Science Committee****Subcommittee on Basic Research****February 22, 1995**

Mr. Chairman, I am pleased to submit this statement for the record. Since the 1940's the United States has reaped enormous benefits from advances in science and technology. Many of these developments are the result of the unique public-private partnership formed after the Second World War to support fundamental research at the nation's universities. This partnership, and the research it has made possible, were valued as an integral part of our national security strategy. But the partnership has also generated discoveries that have benefited our economy and improved our standard of living. In addition, this partnership has been instrumental in providing the educational capacity needed to train scientists, engineers, and a skilled technological workforce.

We are at a time when the rationale, the agenda, and the resources available for research are the focus of an energetic debate. It is one of the roles of the National Science Board to serve as an independent voice for national policy for science and engineering research and education for the Nation. It is in that role that I wish to make two points for your consideration this morning.

The first point is that, in an extremely constrained budget environment, the Administration's budget request for NSF provides strong support across the range of scientific and engineering disciplines and education programs. The NSB strongly feels that this budget -- calling for a three-percent increase overall -- is important in enabling NSF to continue its support of excellence in science and engineering.

In its relatively brief 45-year history of service to the Nation, the NSF has established itself as a cornerstone of America's science and technology enterprise. NSF programs in research and education stand out as remarkable investments that continue to pay rich and varied dividends. Countless advances that yield new jobs, stronger industries, and better schools can be traced back to NSF's discerning support for talented researchers and educators engaged in learning and discovery -- and for the infrastructure that enables their work. For

example, the micro-motors that safely control the airbags in our cars, the gene-splicing techniques that underlie the biotechnology industry, and tools to navigate the World Wide Web, or Internet, all have roots in programs championed for many years by the National Science Foundation.

The second point that I would make is one that goes to the larger decisions you are making in your deliberations in the House. In looking at the budget request for NSF it is also important to appreciate the interconnections of the nation's research and education enterprise. It is the health of the overall enterprise -- the highly interdependent mesh of government, academic, and private sector institutions that comprise our national R&D system -- that we must consider.

Just as the research supported by NSF has provided unanticipated benefits to the nation, the Federal partnership with universities has generated relationships among the various parts of the research community that would not have otherwise occurred.

Last month, the Board issued a statement expressing concern over the potential negative consequences of large cuts in Federal R&D support or significant restructuring of Federal R&D agencies on the nation's scientific and engineering capabilities. I have attached the statement--entitled, "NSB Statement on Federal R&D Budget Realignment," NSB 95-26, February, 1995--to my testimony and I request that it be included as part of the record.

The Board believes that no government program--including those in science, mathematics and engineering--should be beyond careful scrutiny and possible reduction, given the current budget deficit situation. Nevertheless, the Board strongly urges Congress to give careful attention to the fact that restructuring of R&D support at one Federal agency could have a cascading effect of unintended negative consequences across the entire U.S. R&D structure.

The Federal Government established this partnership with universities mindful that the discovery of fundamental knowledge and the development of an educated workforce are in the long-term national interest. The superb research and educational system that has resulted from this partnership has enabled this Nation to be the world leader in science and technology.

Mr. Chairman, National Science Board commits itself to working with you, and all members of the Committee, to develop comprehensive and constructive approaches that will maintain U.S. world leadership in science and engineering.

### INFORMATION FOR THE RECORD

#### Transfer of functions of National Laboratories and selected research programs of the Department of Energy to the National Science Foundation

Any large-scale consolidation or transfer of research functions between agencies could have significant ramifications for the future competitiveness and economic health of the United States. The National Science Board (NSB) recently issued a statement urging caution when structural changes to the federal R&D system are considered. We at NSF urge that proposals regarding the labs' future take these recommendations into consideration.

NSF strongly believes mission agencies such as the Department of Energy (DoE) and the Department of Defense (DoD) must continue to support fundamental research. These agencies are integral parts of a complex and highly pluralistic system of support for research that evolved after the Second World War. In this tightly interconnected arrangement, industry, government agencies and academia each perform complementary roles. Within the federal government, agencies possess unique research capabilities critical to their assigned mission. This system remains the finest in the world.

The National Science Foundation is responsible for supporting fundamental science and engineering across all disciplines, the only federal agency with such a broad responsibility. NSF's unique mandate naturally leads to close contact and interaction between NSF-funded researchers and several of the DoE national laboratories. For example, NSF funded educational programs—including graduate traineeships and fellowships—help assure a steady stream of top-flight scientists and engineers required for mission-related research. NSF-funded researchers also depend on facilities at many of the DoE labs for important fundamental studies in materials science, atomic, high-energy and nuclear physics, and many other areas. Transferring these facilities and their support to the National Science Foundation would have profound consequences for the culture and the mission of the Foundation, and such an action should be studied carefully before implementation.

Several key factors should be weighed before considering changes to the federal support structure for R&D. These include: the degree of overlap between ongoing federal R&D programs; the balance between consolidation and the benefits flowing from the variety of objectives, approaches and cultures inherent in the current system; and the flexibility provided by the current system. Also, questions of accountability to Congress must be answered. Specifically, would consolidation facilitate greater accountability? Would certain areas of research get less scrutiny?

Future funding needs for the national laboratories will be considerable. The national laboratories provide world-class facilities that enable research on the forefront of science. They will require sustained and substantial funding for upgrades and modernization in order to remain at the cutting-edge, irrespective of management or structure.

Changes in the federal R&D complex may be necessary as Congress and the Administration look for ways to reduce the deficit. At the same time, it is critical that we at least preserve -- and even enhance -- the strength of the current R&D system. In particular, any new alignment must foster coordination and cooperation among complementary federal R&D functions.



NSF is working closely with the other R&D agencies to support research in a more efficient and effective manner under the leadership of the National Science and Technology Council. NSF is also participating in the second phase of Vice President Gore's Reinventing Government Initiative, to achieve cost savings within the existing agency structure. Through these interagency initiatives, we are striving to preserve the many positive features and assets of the current federal R&D system, in particular the unique role of NSF, while improving our effectiveness and reducing costs to the American taxpayer.

Princeton University

Woodrow Wilson School  
of Public and International Affairs  
Robertson Hall  
Princeton, New Jersey 08544-1013  
(609) 258-5931  
FAX (609) 258-1985

Julian Wolpert  
*Henry G. Bryant Professor  
of Geography, Public Affairs  
and Urban Planning*

15 March 1995

Ms. Zodie Dempsey  
Subcommittee on Basic Research  
B-374 Rayburn HOB  
Washington, DC 20515

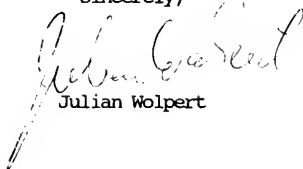
Dear Ms. Dempsey:

I have reviewed carefully the March 7 Hearings and have listed the errors below:

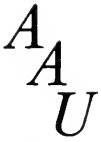
page 12 line 268 "MARRETT" not "MERITT"  
page 14 line 325 "with" not "for"  
line 328 "as" not "is"  
line 331 insert comma after patterns  
page 74 line 1724 Dr."WOLPERT" not "HERMAN"  
line 1730 ditto  
line 1734 ditto  
page 75 line 1752 "firms" not "first"  
insert "after" prior to "all"  
"time" not "timer"  
line 1753 insert "they" after "reports"  
page 76 line 1774 "WOLPERT" not "HERMAN"

Also enclosed is a copy of my written testimony.

Sincerely,



Julian Wolpert



## Association of American Universities

*President*

March 13, 1995

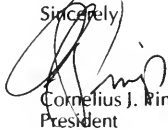
The Honorable Robert S. Walker  
Chairman  
Committee on Science  
Subcommittee on Basic Research  
U.S. House of Representatives  
2320 Rayburn House Office Building  
Washington, DC 20515-6301

Dear Mr. Chairman:

Following are requested changes in my testimony given before your subcommittee on Basic Research on March 2, a transcript of which was received in my office on March 9.

- p. 85, l. 1992: replace last word "in" with "and"
- p. 86, l. 2009: replace "somatic" with "semantic"
- p. 86, l. 2013: replace last word "are" with "is"
- p. 86, l. 2016: replace word mid-sentence "are" with "is"
- p. 86, l. 2017: line should read: "objectives. Sometimes the work is performed under the rubric of strategic"
- p. 88, l. 2060: replace word "preciser" with "pertinent"
- p. 89, l. 2088: replace word "letter" with "lesser"; delete comma at end of line
- p. 89, l. 2089: delete first word "and"; add comma after "engineering"

Thank you for your attention to these small changes. You will note on the attached transcript that these changes are also marked in pen on the text.

Sincerely  
  
 Cornelius J. Kings  
 President

.CJP/jpk

cc: Zodie Dempsey, Subcommittee on Basic Research



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ENGINEERING  
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ASSOCIATE SOCIETIES

American Council of Independent

Laboratories

Association for International Practical

Training

Federation of Materials Societies

National Action Council for Minorities

in Engineering

NACE International

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Engineering and Surveying

INFORMS

Ten Beta Pi Association

The American Society for

Nondestructive Testing, Inc.

REGIONAL SOCIETIES

District of Columbia Council of

Engineering & Architectural Societies

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SUITE 608

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(202) 296-2237 FAX (202) 296-1151

March 17, 1995

The Honorable Robert Walker  
Chairman  
Committee on Science  
U.S. House of Representatives  
Washington, DC 20515

Dear Chairman Walker:

With this letter I am returning the transcript of the testimony on the reauthorization of the National Science Foundation (NSF) that I presented on March 2, 1995, before the Subcommittee on Basic Research. I have reviewed the transcript and request that two corrections be made as follows:

1. Page 35, line 777 -- change "Stave" to "Stayed"
2. Page 37, line 825 -- change "NSF" to "science"

If these corrections cannot be made in the body of the transcript, I would appreciate their being added to the text as footnotes. Please call Kathy Tollerton, Director, Public Affairs, at 202-296-2237 if there are any questions about these corrections. Thank you very much for your cooperation.

On a separate subject, we are very pleased that you have accepted our invitation to address the 1995 AAES Government Affairs Conference at the National Academy of Engineering on March 28th. I look forward to meeting you then.

Sincerely,

*James E. Sawyer*  
James E. Sawyer  
Chair, AAES

Enclosure: Transcript of 3/2/95 hearing

Office of the President  
P.O. Box 805  
Grinnell, Iowa 50112-0810  
515 269-3000  
FAX 515 269-4284

March 15, 1995



The Honorable Steven H. Schiff  
Chairman  
Subcommittee on Basic Research  
B-374 Rayburn HOB  
Washington, D.C. 20515

Dear Mr. Chairman:

As one who testified before the Subcommittee on Basic Research on March 2, 1995, I have edited and am returning the hearing transcript forwarded to me for review. I would like to request that the following information be included in the hearing record:

<u>Page</u>	<u>Line</u>	<u>Proposed Wording</u>
105	2431	of the vital role a strong undergraduate...
105	2438	in a different light. <b>Not</b> as opposite...
106	2446	science professionals, those who <b>will</b> be...
106	2452	students starting <b>with</b> the introductory...
107	2485	program is, <b>to fund</b> it at a level...
107	2486	funding <b>recommended</b> in the Authorization...
111	2576	in the sense <b>that</b> K through 12...
111	2577	is <b>what</b> we are seeing...
116	2697	<b>whole.</b>
116	2701	well, it leverages the federal...

I understand that this letter may be inserted in the transcript in the form of an appendix and referred to by footnote in the main text. Thank you.

Sincerely,

Pamela A. Ferguson  
President

PF:ss



